Vol. 65 No. 8 February 21, 1984

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. Leophyn Beneg & Tiper Spang.

6510 Structure of the Crust Tel Struction of Parish touction

Seismology

ANTO Structure of the crust and urgar mantle
THE SPICINE SPICINE ACROSS AN ACTIVE OCEANIC/CONTICONTAL TRANSCEM FAULT NOWE

Lib. Bern, F.M. Claves Repeatment of Geophysics and
Atternery, University of British Columbia, Vancouver,
Canala vol 1851, P.M. Fills and D.S. Bird

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Vol. 65, No. 8, Pages 65-72

6970 Structure of the crust (Keweenawan Rift)
STPUCTURE UF THE SOUTHERN KEWEENAWAN RIFT FPOT CUCONP
SURVEYS ACKOSS THE MIDCONTINENT GEOPHYSICAL ANNIALY IN
KORTHEASTERN KAYSAS
L. Sarpa (Department of Geological Sciences, Cornell
Universality, Ithece, NY 1683), T. Satzar, H. Farmer,
L. Brown, J. Oliver, S. Kaufean, J. Sharp, and D. W.
Steeples

COCORP profiling across the midcontinent geophysical
anomaly in northerstern Kanesa reveals structural
basins and other features of the Procembrian Feorgenawan
rift buried beneath the Phaneronal cover. The Ad-kmwids main hasin is asymmetric, with a maximus depth of
1 km on the mest and 8 km on the west. The basin fill
is characterized by a lower layered sequence of strong
continuous west dipping reflectors which say be currelated with Hiddle Kaweenawan interbedded volcanic and
clastic rocks apposed along the MGA in the Lefe
Superior region. Overlying that layered sequence is a
some of week, discontinuous reflectors correlated here
with the predominantly clastic rocks characteristic of
the suin besin and appears to be filled predominantly
with clastic sedimentary rocks. The character of the
select date, the seismic velocity distribution, and
gradit, codelling suggest that mark function, and
gradit, codelling suggest that mark function of the
beneath the religion that confects engles to the sestrelinspirate reconstruction indicates that the rift
Disin forced by the rotation of fault bounded blocks
during trustal extension. Although rescrived in many
other rifts profitob by COCORP, the set denace in Inconclusive on this point in the case of the Kansas and
elsewhere suggest that asymmetric sequences of the reflectors are character. elsewhers suggest that asymmetric sequences of layered reflectors are cheracteristic, and perhaps disgnostic, of rife basin deposits in general. (COCORP, Kawannawan rife, didcontinent geophysical anguely).

Tectonophysics

8110 Convection currents THE INTERACTION OF A SUBDUCTING LITHOSP.

BLAB WITH A CHEMICAL OR PHASE BOUNDARY.

U.B.Christonsen (Mak-Planck-Institut, Sear-strasse 21, 6500 Hainz, PR Germany), D.B.Yuen U.R.Christoness (Mak-Planck-Institut, Smaretrass 21, 5500 Mainz, PR Gormany), D.A.Yuan
Mo have used a finite alosent convection
model to determine the conditions for panetration of the subducted plate into the lower
mantia. A temperature dependant non-Newtonian
rhoology is used to achieve plate-like
behavior of the upper and sinking thermal
boundary layer. The 650 km discontinuity is
taken as either chemical or phase boundary or
a combination of both. It is represented by a
marker chain which effect additional buoyancy when distorted. When the compositional
density contrast is greater than about 5t the
defiscted sidewards at the boundary and twolayer convection preveils. A resulting depression of the boundary by about loo km
should be detectable with selepic methods.
Solow 51 the slab plunges several hundred
kilometers into the lower mantle and below 28
livell probably not stop before the core
mantle boundary and extensive mixing is
expected. With a pure phase change a negative
clapsyron slope of about 6 MB/K is required
to establish a type of 'jesky' double layer
convection. A more moderate slope cam aid a
mail chasical density contrast to prevent
ties shout the physical nature of tha 650 km
appears possible of dynamical gradies.

A Geolow, Rapry 8, February 15, 1 February 21, 1984

Sign Tectonophysics
ORIGIN OF CHYOTS: THE BEAGLE TO SKAREAM
II. M. Monard (Institute of Marina Resources and Scripps
Institution of Occanography, La Jolia, CA 92093)
Thermal subsidence would have drowed speint volcasic
Islands (DAVI). Ancient volcances, if active at present
rators in the main occan hashes, would have produced
1.5-3 those the observed number of DAVI. Shallow-water
indicators have been collected from 11% of guyots and
another 1% appear to be drowned barrier rasis or stells
on veilaction profiles. A stininum of 55% of DAVI its
down dwift from hot apoet that generate volcanic
islands. The DAVI have the same 3-4 km ralief as the
lalands would have if truncated. Monatheless bypothess
of a constructional origin of guyous continue to be proposed. Relative to these hypotheses are the following;
(1) all four large, active submarine volcances that has
been surveyed lack flat tops and (2) many small, despiinactive, relatively flat-topped volcances are constructional forms but none with more than 2 km of relief are
shown to be. Thus it is probable that all guyous with
more than 2 km of relief are DAVI but the possible aristence of larger constructional forms is not excluded.
There is no evidence that guyota large quough to be of
intoreast in studying the speirogenic history of sidplate swells are not DAVI.

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Volcanology

8599 Vulcanology (Volcanic Stratigraphy) STRATIORAPHIC RELATIONS AND SOURCE AREAS OF ASH-FLOW GREETS OF THE BLACK MOUNTAIN AND STONEWALL MOUNT

Sept Volcanciony (Volcanic Stratigraphy)

STRATIORAPHIC ENTITORS AND SOURCE AREAS OF ASH-FLOW SHEETS OF THE BLACK MOUNTAIN AND STONEMALL MOUNTAIN VOLCANIC CENTERS, NEVALIA

D. C. Noble (Mackey School of Mines, University of Nevada - Reno, Reno, Navada 8955). T. A. Vogal, S. I. Visas, J. W. Evrin, E. H. McKee and L. W. Younker Rocent work has teaulted in mojor changes in this stratigraphic correlations and source-area sasignames of ash-flow sheets of the late Nicene Black Hountain and Stonewell Mountain volcanic centers, southern Nevada. Ash-flow that's exposed around Stonewell Mountain was different trace-closent patterns and the moments of the Thirsty Canyon Tuff, suppled from the Black Mountain center, with which they were previously correlated. Mafinius concentrations are patterns and the Cival Canyon Macket of the Stonewell Hountain the Stonewell Mountain the Stonewell Mountain the Stonewell Mountain area, havein maged the Cival Cat Canyon Macket, can be traced corthward continuously from outloy from outloy from outlow the Canyon Macket. Cat Canyon Macket, can be traced corthward continuously from outlow from outlow the Canonal Mountain wolf from outlow from outlow the Canonal Mountain wolf-low sheet of the Stonewell Mountain the Canonal Mountain wolf-canic conter; they are herein assigned to a new farmation, the Stonewell Frat Tuff of lere Mocanu age Tuffs previously shaped hear Black Mountain set the Cantillow sheets of the Stonewell Mountain wolf-canic conter; they are herein assigned to the Spearhead Macket in the Black Mountain set of the Stonewell Mountain set of the Stonewell Mountain set of the Stonewell Plantain Stonewell Mountain canter is thus alleged Mountain set of the Stonewell Plantain sense are teassigned to the Penture Mead Nawbor (new) of the Thirsty Canyon Tuff. The Stonewell Hountain season are teasigned to the Penture Mead Nawbor (new) of the Thirsty Canyon Tuff. The Stonewell Hountain sense are teasigned to the Penture Mead Nawbor (new) of the Thirsty Canyon Tuff. The Stonewell Hountai

E. C. Bullard's First **Heat-Probe**

Elizabeth N. Shor 2655 Ellentown Road, La Jolla, GA 92037

Sir Edward Bullard in 1973 said to me, Betty, I want to tell you how my first ocean heat-flow instrument was made in the sunmer of 1949." He was then on his annual 3month visit to Scripps Institution of Oceanography and knew that I was writing a history of the institution. Teddy (as he preferred to be called) was proud of his participation in measuring the flow of heat at sea. The instrument that he described that day never made a heat-flow measurement, but it did establish the technique that has been used for more than 30 years.

The following account is a slightly shortened version of our taped conversation on August 5, 1973 (the original audio cassette is in the archives of Scripps Institution of Oceanography, item 81-84). Unfortunately the reader loses the charm of Teddy's voice and accent, but here for history are his

Bullard: I first became interested in heat flow in the early 1930's. I'll send you a copy of a paper that describes some of the background of the early work on land [Bullard. 1939]. It was the British Association, which is like your triple-A S-had a committee on the subject, with Flarold Jeffreys on it. In the period just before the war I was developing methods of making heat-flow measurements on land, which had been done extraordinarily badly before, and hardly anything had been done since about 1880. There was a previous British Association committee way back in the 1880's, and I have written a historical paper on this. The historical paper is in Willie Lee's book on heat flow [Bulland, 1965]. He'd asked me to write a summarizing chapter for the book, and I said I wouldn't do that, because it's too dull a thing to do, and then he wrote to me and said he thought this was most imreasonable and improper of me, and he saw no reason why I shouldn't write a summarizing chapter. And so I wrote an historical chapter which was really a sort of joke chapter and was mostly about the study of heat flow in the 17th century. But it does give the more recent stuff.

Well, then, shortly before the war I began to think about measuring heat flow at sea. And the war in '39-the war overtook the plan, and we didn't do anything about it. Shor: Had you developed an instrument at

Bullard: No, I had developed the ideas for the instrument but we had done no hardware development, but I knew what I wanted to do. And we had two schemes for doing it: one was the one we eventually adopted of putting a spike in, and the other was the idea of putting a kind of mattress on the seafloor and leaving it there and measuring the temperature gradient through it. Then, after the war I couldn't do this because I couldn't get a ship. Discovery was being used for replenishing lighthouses, and there was no British occanographic ship available immediately after the war. Then I tried to get Maurice Ewing to cooperate. He said he couldn't spare any ship time for this purpose. He'd just gone to Lamont. I'd known him-I'd been to sea with him before the war when he was at

Lehigh, in connection with seismic work.
Well, then I went to Canada. I took a job in Canada, going up there in March 1948. And in the summer of 48 I paid a brief visit to California. It was my first visit to La Jolla. Louis Slichter used to run a conference on geophysics every year [at the University of California, Los Angeles]. I went to that, and Louis brought me down here afterwards, and I came down here and met Roger Revelle and Walter Munk. My memory is that I went to a party at Roger's, and I met a lot of blondes. I remember La Jolla as being blondes.

l got on very well with Waher and Roger. They asked me to come back the next summer. I forget exactly when, but I got a letter inviting me to work for the summer down here, and I said there were several things I'd like to do and one of them was the heat-flow measurement. And I came down here, probably June, July 1949. And I got here and it was suggested that I take on Art Maxwell. who was a graduate student.

Elizabeth N. Shor was raised in Lead, South Dakola, attended Pasadenii City College (1 year) and Wellesley College (2 years). She has learned a bit about geophysics from George G. Shor, Jr., whom she married in 1950. She has writ-N 11 30 ten two books on the history of paleontology, one on the ory of Scripps Institution of Oceanography (where George works and she has worked), and a number of biographical accounts of scientists, especially for the Dictionary of Scientific Biogra-

Well, anyway, I decided to do two things: to investigate the westward drift of the earth's magnetic field, which was a data analysis problem, and to try and build an apparatus r measuring heat flow. Well, then I went to Roger and said we'd like some workshop time. And Roger said he was sorry, the workshop was completely taken up with urgent work, and it was impossible to give any work-shop assistance. So I decided that we'd build the thing ourselves. So I went around to the fellows and I hadn't got any workshop assistance-couldn't we work in the workshop, Art Maxwell and myself? This was obviously a slightly embarrassing matter. But we went down to the old workshop in the old shed. I got an office-I shared an office with Walter Munk, over the old director's office in the

original building of Scripps.
Well, we settled down. This was a substantial job. We designed what-it was the first time I think that anyone at Scripps had had a watertight equipment for use in the deep sea. I remember the expert advice from [John D.] Isaacs, and so on, was very much against this. They wanted us to build an equipment that was full of oil — the recorder, the electronics and everything immersed in oil. And I decided against this, I decided to build a watertight apparatus made watertight with O-tings. That was, I think, brand new. And we had some interesting experiences with it.

First of all, we had great difficulty in getting sufficiently strong tubing—alloy steel tubing seemed not to be available to sort of 1inch thicknesses 6 inches diameter. We eventually found that the people who made ball races—ball bearings—made them by slicing then off seed tabes, and one of the manufac turers of ball bearings and ball races supplied us with a piece of tubing. And we got some end plates out of good alloy. The stuff was about 6 inches internal diameter and about three quarters of an inch thick, something like that. And we made up things out of this with O-rings. Of course, the O-ring had been introduced originally for aircraft-hydraulic systems during the war and was then introduced into the manium diffusion plant as a matter of making it pressure tight. And I'd known of it from these sources. And we decided to use this. And it proved extremely effective. We went out and tested these containers, and we never had a leak. Eve never had a leak from an O-ring container at sea. They're used in everything now of contac-They're used in cameras and seismic equipment and all kinds of things.

And we made a very chinsy apparatus for this purpose. We decided to do something which I thought I understood rather than something I didn't. So we bought-at least I got from the British Admiralty—galvanometers, which were very robust and which could be used horizontally. And we fixed these and used photographic recording and thermocouples. So it was thoroughly old-fashioned equipment: no electronics; photo-graphic recording, galvanometers, reversing switches for eliminating thermal emfs in the equipment. And this equipment I afterwards used myself, so it is the equipment I describe in my first paper [Bullard, 1954]. Well, we decided to allow the full pressure

to come on the probe itself. So the probe itself was filled with oil, and the recorder was full of air. And we had pressure-tight connections between the two, and—sort of looking back-the whole technique of fitting the con nections through—I remember we had a good deal of trouble with getting the connec-tions through, and eventually I decided there was too much advice in the workshop on this, and I took the end plates home. I took this home, and heated it on a gas range and soldered the connections in-little glass connectors with a little metal skirt, and soldered

Shor: Was Art Maxwell working closely on Bullard: He was working on this-we were

both working on the lathe making this thing. Of course, we had to make this photographic recorder; you see, we had to make a photographic camera and all the associated supports and things. Well, anyway, we made this apparatus in the course of about a couple of months. And we took it to sea. We had trouble in getting ship time. What we wanted was a day or two of ship time to go out and test it, you see. We did all the testing. I remember the first testing we did, we bullt a sort of gallows down at Mission Bay [in San Diego]. which was then a marsh, of course—and strung the apparatus up with the galvanonieter and things in it and climbed up a ladder and cut the ropes and let it drop to see if it would go into the mud and see whother the shock would break the galvanometer and all this kind of thing. Anyway, we then tried without any galvanometers in to see if we could get it into the mud out in the trough off San Diego. There was a tremendous amount of sort of testing to be done. It was an entirely new thing really.

We discovered the trouble that if you put a

thing into the bottom and left it there you couldn't avoid pulling it and bending it, and we tried tubes of various lengths and various

diameters, to see what we could do. And we more or less discovered what we could do and what we couldn't do. And finally we took it out for a run with the whole apparatus to try and measure the heat flow-and we got no records at all. Everything worked. Except we didn't get any records. And we spotted what it was. It was condensation on the mirrors of the galvanometer, which we'd notthought of hetore. So we put drying equip-ment in and got rid of this. But we never got any results that summer, and I went home [to-England). I was director of the National Physical Laboratory [NPL]. I went home and had another similar apparatus built, and 4 got

results with that. That was built of course by the NPL workshop. We had some of the best workshop fa-cilities in the world. I was at home. I had superb facilities and no question as to who was going to use them. You see, I was director of an operation spending many millious of dol-lars a year. If I said do something, they did it. And so I had proper working drawings made of the equipment and had it built in a proper workshop and so on. And we took it out and it worked every time.

Shor: You tested it then off England? Bullard: Yes, I'd done all the testing here so I just made a new apparatus and took it out to sea and it worked.

Now that's all been published, so the dates on this are all known. I'll give you all the references. Our list paper was published in the Proceedings of the Royal Society. You know the two letters in Nature, do your Shor: No.

Bullard: Well, I'd better find these for you (Revelle and Moxwell, 1952; Bullard, 1952). What happened was this. There was a littlewell, not exactly a misunderstanding -but I understood that the group here and ourselves were going to publish a joint paper. And I was very busy and I held up publication of our work for some time, and evenually the [Revelle and] Maxwell letter to Nation went in, and I put a letter in in the same number. Well, then afterwards we published a joint paper [Bullard et al., 1956]. There was

bit of a muddle about publication. Do you know -now I come to think of it. the business about taking the thing home tomake the go-through connection was at NPI; it was the NPL workshop that was making a scene about go-through connections -pressure-right connections in heavy plates. And I took it home and did it on my domestic gasrange. And I think this rather shook the place, to have the director take bome the thing and actually do the soldering when they said they thought they couldn't do it. That was in England. It wasn't here. We did it here without any biss. We did it om selves in the

The workshop manager was very good to us and very mee to us. And eventually, actually, some of the heavy machining was done. I said to him one day, I said, "Look, do you want us doing the beavy machining? These are big lathes. We're not professional mechanics. We're turning considerable material. these alloy steels. Wouldn't you rather do this yourself?" And they did-the acrual outer container was machined by the workshop staff in the end. But we machined the rest of

Now there is a complete description—the apparatus we had here is essentially the same as the apparatus I built in England.

So that's essentially the story. And then afterwards Art Maxwell, Roger [Revelle], and i wrote a summarizing article on the whole subject. It's a review article about heat flow. The critical things to look at are those two letters in Nature, which are the first publications, then there is my paper in the Proceedings of the Royal Society describing my own ments, and there's our joint paper with Roger.

So ended Bullard's verbal summary in After the unsuccessful trials of 1949, the

original instrument at Scripps Institution was "discarded in layor of using thermistors in a bridge network with an amplifier and homebuilt recorder," said Arthur E. Maxwell (personal communication, June 21, 1983). He worked with Scripps engineers James M. Snodgrass and John D. Isaacs on the improved model during late 1949 and early 1950. That heat-probe was used on the Midpac (sometimes called Mid-Pacific) Expedi-

Forum

Global Positioning Technology

In an otherwise excellent article (* The Impact of VLBI and GPS on Geodesy," Eos. September 27, 1983, p. 569), Dr. olm D. Bossler inaccurately reports that the Macrometer, a single channel receiver which came to market only last year and is restricted to relative position use was the first global positioning system (GPS) receiver to become commercially available.

As many in the geophysics community know, Stanford Telecommunications, Inc. (STI), has provided GPS receivers and transmitters commercially for almost 5

STI dual frequency GPS Geodetic Recievers, owned and operated by Shell, NSWC, IBM, and Draper Labs have been used in numerous absolute and relative positioning experiments. In one such exeriment, analysis of 5 hours of four satelite phase measurements yielded relative osítion coordinates on a 28-km baselme. which were repeatable to 30 cm in height. 50 cm in E-W direction, and 10 cm in N-S

STI GPS recievers have been used on the North Atlantic aboard the CSS Hudon by Norrech, University of New Brunswick, and the Canadian Hydrographic Survey. Here a real time Kalman lifter was used to combine GPS ranging and slops motion information to update an inertial navigafioual system. Further, STTs self-contained model 502B receivers provide nattime positioning with precision on the order of 20 m with no postprocessing

Lectowed Staff Stanford Telecommunications, Inc. Santa Claric, UA 93050

Lapologize to Dr. Perreault and State ford Telecommunications, Inc., for nolack of precision in the subject article. V more proper statement would have been

The first receiver to become commercial be available to continents here environed to the Macrometer Model V-1000 Invalero metric Surveyor, manufactured by Marto metrics, Inc., of Wolmen, Massachuseus We at the National Geodetic Survey are well aware of the important role placed by STI in the development of the GPS sys-

> Director of Charling and Combitte Service -NOAARockelle, MD 20852

Biography of Wiechert

For a biography I am writing of Emil Wiethert (1862–1928), professor of geophysics at the University of Contingen. would appreciate hearing from any readers who might have material of interest. Photos, letters, and anecdotes about his life are all welcome.

> Wilfried Schroder Hechelstrasse 8 D-2820 Bremen-Rönnebeck Federal Republic of Germany

tion, carried out by the Scripps Institution of Oceanography and the U.S. Naval Electronics Laboratory during the summer of 1950. (The name of this expedition is given incorrectly in Bullard (1965) as Capricorn Expedition. which was in 1952.) The first successful occanic heat-flow measurements were taken on that expedition. (As noted in various of the early papers. Hans Pettersson described oceanic heat-flow measurements that he took in 1948; Bullard considered these invalid.)

Bullard, as he said above, returned to England and in 1952 (or 19515) at the National Physical Laboratory had an instrument built that was "similar to the original one" [Bullard,

Atticle (cont. on p. 74)

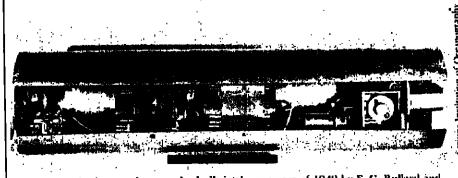


Fig. 1. The heat-probe recorder built in the summer of 1949 by E. C. Bullard and

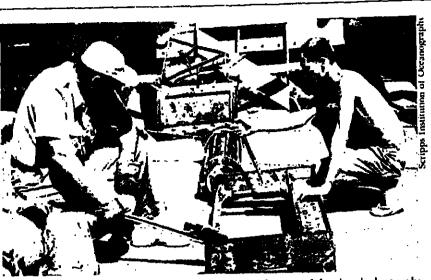


Fig. 2. Arthur F. Maxwell (right) and James M. Snodgrass straightening the heat probe after one of its lowerings on the 1950 Midpac Expedition.

Article cont. from p. 73;

1954) It is difficult to determine from the detailed description of this instrument in that reference what modifications be and his laboratory may have made of the original design. Bullard obtained his hist heat-probe measurements with the NPL-built distrument in July 1952 from R.R.S. Discovery H in the Atlanto.

Manner Fwing, at the Lamont (now Lamont-Doherts) Geological Observatory, set out to income heat flow after using a hornowed Bullard probe in 1953 that failed to work by 1957 Robert Gerard and Fwing had descloped a needle-probe device for measuring heat flow that was attached to the roulinely need piston cover [Grand et al., 1962].

What was so exciting about those early ocanic measurements of figat flow? As Bullard [1965] charmingly reconntrol in the historical introduction to I ce's book. Terretural Heat Flow, two commutees of the British Association for the Adsaucement of Science, one in 1868 and one in 1935, had been appointed "to consider" underground temperatures and thermal conductivities in mines. Bullard conducted some of the experimental work for the 1935 committee, and, typically for whatever he was doing, he became intrigued by the locabili of the subject. What might be different about the deep ocean?

The state of the art was summarized in the Bulland et al. (1956) paper.

there are only a less dozen reliable measurements of fieat flow on the continents. The values range between 0.5 and 3 prollom/sec is most of them being between 0.8 and 1.1. The mean is about 1.2 greatenisses.

The commental heat flow is easily accounted for by the radioactivity of the continental rocks. Since a large part of the material above the Mohorovicie discontinuity at a depth of about 35 km must be gramme or similar rocks, and since some heat must come from below the discontinuity, the difficulty is not so much to find a control for the observed heat as to explain why the flox is not greater than it is...

The petrological study of oceanic rocks and seismological work at sea have shown that the criest beneath the ocean basins is strikingly different from that underlying the comments.

In view of the striking differences in petrology and structure between the oceans and the comments it might be expected that the heat flowing from the oceans would be only a from of that from beneath the confinents. In Lact this is not so Since the oceans rover 71% of the

earth's surface, a releable a stimate of the amount of hear flooring through their floories of great importance in discussions of the critics thermal history. The occanic tore continues are not, however, merels an addition to the confinental ones; in view of the functional differences between the occans and the continents the hear flow at tea power a problem so parate from that of the commental hear floor

Immediately after the Midpac Expedition, Revelle vesite to Bull rel of tober 15, 1030; carbon of letter is academies of the Scripps Institution under Expeditions Malpac);

We managed to get at least sixen good measurements of temperature gradients in the bottom made. All four one of these indicate a quadrent atomid 0-42 T per meter. If your conductivity estimates can be used, this nearly that the feat floor from the sea floor is the same as that from the continuents. It me, at least, this is a very surprising result form apparently you data suspensed it all along.

Mostly and Monad [1932], in their letter in Nature, effect six measurements, with the comment. In a noteworthy that at five of the six feasible occurring a total distance of nearly three thousand miles the computed hear flow becoming in percent of the average value. In the continuous.

for the continents.

Bullard [1952], hi the letter to Nature, said that the "continuination by Revelle and Max-

well [from the Midpac Expedition] gives a result which is completely unexpected, and demonstrates again how little we know of

submarine geology."

When Bullard first concerned himself with measuring the flow of heat through the ocean floor in 1939 and had the opportunity at Scripps Institution in 1949, the technic demarcation between land and sea to geologists was sharp. Every bit of evidence was needed to understand the whole earth. As measurements accumulated, patterns of variation in heat flow through the ocean floor began to emerge, and orders of magnitude for "average" values improved. Langoth and Von Herzen [1970, p. 299] moted that "a surface flux of up to cight times the earth's average is observed near the axis of the mid-oceanic ridges."

ridges."

Those early heat-probe measurements, acquired with "a very clumsy apparatus" that began in Buffard's mind and hands, contributed considerably to the global knowledge of today's geophysicists.

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Edward C. Bullard 1907–1980

Professor Sir Edward Bullard was honored by his Queen in 1975 as a "world leader in geophysics." Each of those words is apt: "world"—her arise indeed the earth was his domain, in theory, and field work in civilized

and remate regions, and at sea;
"leader"—herause after listening to and
conversing with students and colleagues be
calged them toward carrying out large ideas

troin half-formed thoughts;
"geophysics" —a held between prerise physics and imprecise geology that came into being only because a few outstanding and versatile scientists like Bulland could span the

breadth.
"Chance led me into geophysics at a wonderful time," he said, "and it has been among
the most rewarding experiences of my life to
have played a part in the transformation of a
backwater into a bandwagon" (Bullard,
14975M.

Teddy Bullard carried this off with a unique charm, with a near-Purkish humor, and with an interest in people that made every chat with him memorable and every lecture by him a keen delight. His legacy will prove to be more than his own considerable scientific endeavors; it will include the accomplishments of his students and colleagues and a better effort even by his casual acquaintances. It has been said: "The thing looked so simple when Teddy explained it, it was only later you realized how deeply he understood [Matheus, 1980].

He was an outgoing man, quite lacking in pomposity, yet very aware of status in his acquaintances. He observed the differences but never made invidious comparisons between his homeland and his adopted home country. Although he appeared disinterested in hon-

ors, one sensed that they pleased him.

Edward Crisp Bullard was born on September 21, 1907, in Norwich, England, where his tather's family were brewers. In his early years he was not an outstanding student, but during high-school years he developed a keen interest in physics through a teacher. He entered Clare College, Cambridge, and graduated with first-class honors in physics. In 1929 he became a graduate student in the Cavendish Laboratory of Lord Rutherford, from which he received his Ph.D. in 1932 with a dissertation on the scattering of slow electrons in gases.

The first position available to the young physicist in those depression years was for the Department of Geodesy and Geophysics at Cambridge, as a demonstrator in surveying. As such, according to Bullard (who wrote a tribute to himself at the request of Walter Munk), he "embarked on a very profitable eight years in which he learned the elements of Earth science and carried out a remarkably diverse series of projects. The success of these was in large part due to the steady support of [Colonel Sir Gerald] Lenox-Conyugham, who was not at all disturbed when told that the police were hoking for the perpetrators of an explosion which had left a hole in a road in Leicestershire" [Munk, 1978].

The first in the diverse series of projects was measuring small variations in gravity, for which Bullard developed an elegant technique for timing the swings of an invariant pendulum. The work was done during 1938–1934 in the East African Rift Valley, where on one occasion he and his wife Margaret were treed by a lion.

The explosion that disturbed the police was part of a group program to map the Paleozoic layer beneath eastern England by means of seismic refraction. At the 1936 meeting of the International Union of Geodesy and Geophysics in Edinburgh, Bullard met Princeton geologist Richard M. Field. It was Field's insistent theme that geologists must study the ocean thoor. Bullard [1975a] said: "He would not take no lor an answer, he would not stop talking, he had no doubts, he was embarrassing and sometimes a misance, and yet he struck the match that set earth science alight.

... He invited me to the United States in 1937 ... and sent me out to sea with the Coast and Geodetic Survey and with Maurice Ewing." Upon his return to England, Bullard began seismic studies with Thomas F. Gaskell in the western approaches to the English Chantel aboard two Brigham sailing trawlers.

As a third venture into the young field of geophysics, Bullard measured the temperature gradient, or heat flow, on land in England and in South Africa in 1938–1939. This was for a committee of the British Association for the Advancement of Science, appointed in 1935. Work of this kind, said Bullard once, "had been done extraordinarily badly before" [Shor, 1984], and elsewhere he noted: "Great difficulty was experienced in finding suitable (bore)holes, but very satisfactory results were obtained from those that were found" [Bullard, 1965]. The project led Bullard to pondering a means of measuring heat flow in the deep ocean.

heat flow in the deep ocean.

On the advent of World War II, Bullard became an Experimental Officer in the Naval Scientific Service, first to develop methods for protecting ships from magnetic mines, then to develop methods for sweeping acoustic and magnetic mines. He moved on to intelligence investigations pertaining to the German development of rockets and to a study of the most economical ways of attacking firing sites in France. The Times noted that Bullard "built up around him an astonishingly versatile and effective establishment which, in the urgency of time, had when necessary, an utter disregard for the formalities



At the change of command in 1976, the Albatross Award of the American Miscellaneous Society was transferred to Edward C. Bullard (right) from Roger Revelle (left). It's a scruffy bird, but a signal honor.

of normal civil service rules, and thus moved with a speed impossible for other establishments" [Matthews, 1980]. His participation in matters for the Ministry of Defence continued for many years, and he served on the committee for a nuclear-test ban treaty also.

Bullard returned to Cambridge in 1945, where he found the laboratory in a shambles after 6 years of disuse, but he got it into operation and soon became head of the Department of Geophysics. The lack of research funds and lack of access to a research ship frustrated him to the extern that in 1948 he accepted the position as head of the Physics Department at the University of Toronto in Canada. There he initiated theoretical inquiries into the source of the earth's magnetic field, using the early computer system ACE, Bullard's long-pursued work on dynamo theory of the earth's core constitutes his most profound single contribution to knowledge of the earth.

In 1950 Bullard returned to England to succeed Sir Charles Darwin [grandson of the author of The Origin of Species] as Director of the National Physical Laboratory at Teddington. While chafing some at the responsibilities, he felt that he was an effective director, and he was able to do a substantial amount of his own researches. In fact, "through his position as director he was able to deploy the entire resources (by no means inconsiderable) of the computing division to carry out extensive numerical work required for the development of his [dynamo] theory" [Massey, 1980]. The position and his competence gained him a knighthood in 1953.

Bullard in 1956 resolved his indecision about what kind of life he wanted by returning to Cambridge, again as head of the Department of Geodesy and Geophysics. There he felt that his primary commitment was to his own work and to helping a large number of very able graduate students. It was an era of ferment in the expanding field of geophysics, and Cambridge became a focal point. In 1968, for instance, Harry Hess, J. Tuzo Wilson, Drummond Matthews, and Fred Vine were all at Cambridge, and Bullard was reassembling the continents by computer with deceptive simplicity [Bullard, 1964]. Seafloor spreading and plate tectonics were launched. and for those theories Teddy Bullard was a primary catalyst.

In his Cambridge years he also directed a major investigation into electromagnetic induction in the earth; he helped in establishing the technique of determining the age of rocks by the potassium-argon method; and he encouraged the application of modern computer techniques to geophysical problems. Always he was interested in the history of science, and he assembled a considerable library in it. This seemed to be an outgrowth of his interest in people: for an individual's memorial account he wanted to know not only the science but also the minutest details of that person's life. He quite enjoyed writing historical summaries of aspects of geophysics.

Bullard's association with Scripps Institution of Oceanography in La Jolla, California, began with a brief visit in 1948, followed by a 2-month stay in 1949 when his first heatprobe was developed [Shor, 1984]. From the nid-1950's he was a frequent visitor to Scripps, where from 1963 to 1977 he held a part-time appointment as professor of geophysics. When he retired from Cambridge in 1974, he moved to La Jolla permanently. There he continued to work vigorously on what he called "his favorite topics of plate tectonics and the origin of the Earth's magnetic field," and he was drawn into an advisory role to the U.S. government on nuclear-waste disposal. In all, he published some 200 papers (a memorial account and a complete iography will be published by the Royal Society of London:

Society of London).

Bullard married Margaret Ellen Thomas in 1931; they had four daughters. Margaret was the author of several novels situated in various places where the family had lived. In 1974, Bullard married Ursula Margery Curnow of New Zealand; she is an accomplished painter and sculptor.

This giant in geophysics died of cancer on April 3, 1980, in La Jolla. Only a few hours before his death he approved final changes on the paper "Direction of the earth's magnetic field in London, 1570–1975," with Stuart Malin of Edinburgh. Teddy made life interesting, and he faced death with courage.

Awards to Edward C. Bullard

Sedgwick Prize, 1936

Fellow, Royal Society of London, 1941
Hughes Medal, Royalty Society of London, 1953
Foreign Honorary member, American Academy of
Arts and Sciences, 1954
Chree Medal, Physics Society, 1986
Foreign Associate, National Academy of Sciences, 1959
Day Medal, Geological Society of America, 1969
Gold Medal, Royal Astronomical Society, 1965
Agassiz Medal, National Academy of Sciences, 1965
Wollaston Medal, Geological Society of London,

Veilesen Medal and Prize, Columbia University, 1968 Royal Medal, Royal Society of London, 1975 Bowle Medal, American Geophysical Union, 1975 Albutross Award, American Miscellatteous Society, 1976 Maurice Ewing Medal, American Geophysical Union, 1978

Union, 1978
The facilities of the Cambridge Department of Geodesy and Geophysics were named the Bullard Laboratorios in 1980.

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This tribute was contributed by Elizabeth N. Shor, La Jolla, CA 92037.

EOS

The Weekly Newspaper of Geophysics

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Subscription price to members is included in annual dues (\$20 per year). Information on institutional subscriptions is available on request. Second-class postage paid at Washington, D. C., and at additional mailing offices. Ecs. Transactions, American Geophysical Union (ISSN 0096-3941) is published weekly by

American Geophysical Union 2000 Florida Avenue, N.W. Washington, DC 20009

Cover. This weak-beam micrograph shows a twist boundary in an experimentally deformed olivine single crystal from San Carlos (Arizona). It was taken with a 125 KeV transmission electron microscope. The scale bar is 2200 nm. Such orthogonal arrays of screw dislocations are also commonly observed in naturally deformed peridotites. They are produced during deformation or annealing events either in the earth's mantle or during the ascent of the olivine-bearing bodies to the surface. The micrograph was taken by Daniel L. Ricoult (advisor: D.L. Kohlstedt), Department of Materials Science and Engineering, Cornell University, Ithaca, New York.

An Invitation Would you like to be on the cover of

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<u>Yews</u>

Cretaceous Boundary Four years after it was first proposed

Four years after it was first proposed, the theory that a colossal mereorite struck the earth 65 million years ago continues to build toward a consensus—this despite recent findings that volcanic eruptions might also have caused the "iridium anomaly" that is the impact theory's best evidence (Eos. February 7, 1984, p. 41).

High concentrations of iridium at the Crescover Testians beauty of the proposed of the concentrations of the conce

taceous-Tertiary boundary were first noticed in sediments from Italy. Denmark, Spain, and other locations around the world by Walter Alvarez, his father Luis, and their Berkeley colleagues. They concluded that the source of the extra iridium must have been extra-terrestrial because the element shows up in crustal rocks only in very small amounts and no one could think of a mechanism that would distribute iridium from the mantle so widely around the surface of the globe. The Alvarez group posulated that a meteorite about 10-km wide had collided with the earth, throwing up a planet-encircling cloud that blocked out sunlight, ended photosynthesis, and snuffed out many of the land and sea creatures of the Mesozoic, including the dinosauts.

Until recently, the inidium anomaly was virtually the only support for this idea. In November, however, two researchers from Yale University, Jean-Mart Luck and Karl Turekian, reported what may be even more compelling evidence. They analyzed osmium isotopes in boundary-layer rocks from Denmark and Colorado-osmium is another platinum group metal that shows up anomalously high in these sediments—and found nearly equal amounts of 187Os and 186Os, an isotopic ratio much more characteristic of meteorites than of crustal rocks. Luck and Timekian had Inst hypothesized that if a normal geochemical process such as precipitation from seawater had concentrated the osmium, they would see the higher ratio found in terrestrial rocks. After examining a number of oceanic manga nese nodules, they found that this was indeed the case, and so concluded that it was a meteorite impact (or possibly two impacts, since they found different ratios at the two sites) that deposited the osmium.

With this new information, is there now a consensus on the meteorite theory? Not yet. says Charles Orth of the Los Alamos National Laboratory, who provided Luck and Turekian with the sample from Colorado's Raton Basin and who was the first to find the iridium anomaly in freshwater sediments, "We Gan't yet lay to rest a volcamic source-- we need to learn more about the platinum metal ratios in the mantle." Recent findings at Kilauca in Hawaii slow that iridium can be concentrated on the surface after settling out from volcanic emissions. It would have required an enormous explosion to distribute this volcanic material globally in the Cretaceous-Tertiary boundary layer, however, and the sort of slow, oozing flows that normally accompany eruptions like Kilauca are not consistent with this.

accompany eruptions like Knauea are not consistent with this.

Most frustrating of all for the meteorite-theory faithful is the continuing lack of any evidence of an impact. So far, about 100 craters around the world have been evaluated as possible candidates, according to Thomas.]. Abrens of the California Tusinute of Technology, "but none seem to be the right size and age." For this reason, many people favored the idea of an occan impact right from the start. After all, Abrens points out, the climate was warmer 65 million years ago, water wasn't locked up in polar ice caps, and there was more ocean.

An orean impact would also explain why no crater has been identified—more than half the ocean floor that existed 65 million years ago is gone, subdirated back into the mande. Furthermore, recent reports of small spherods that appear to be altered "impact droplers" of basaltic origin (found in boundary layer clays in northern Italy and the central Pacific by Alessandro Montanari and colleagues at Berkeley) make the case for a seafloor impact even stronger. But where are the remnants of the great isomarins and sobmarine landslides that would have followed such an event: No one has yet come up with a good answer.

a good answer.

Meanwhile, Charles Orth and others are looking for iridium anomalies at other periods in geologic history. This leads to another question: If meteorites do occasionally hit the earth, are they responsible for mass extinctions; Orth and various coinvestigators have checked for high iridium concentrations in clays known to be deposited during other pe-

riods at wholesale extinctions, including two trilobite-brachiopod boundaries in the late Cambrian, where they found no iridium anomaly. Only has also thecked boundary layers from the Ordovician-Silurian and the late Devonian. No anomalies there, either. But he continues to search for other examples of indium excess across time and plans to widen the geographic range of his studies of the Cretaceous-Tertiary boundary layer to establish a more global pattern.

establish a more global pattern.
Walter Alvarez, with whom it all started, will have a paper in Science next month in which he counters the counterargament that the extinctions at the end of the Mesozoic were gradual and so couldn't have been caused by one caustrophic event. Alvarez and his coauthors, based on a review of the existing paleontological literature, see "a sharp dropoil" right at the iridium-rich boundary layer for four groups of marine invertebrates: ammonites, one group of bryozoans, brachiopods, and bivalves. "Some paleontologists have said that the drapaffs were more gradual," Alvarez told Eos, "but we looked back at the record, rather than what they say the record shows."—TR



Planetary Science Budget

The fiscal year 1985 budget for the solar system exploration program of the National Aeronautics and Space Administration (NASA) is very promising (m/5Eos, February 14, 1984, p. 49). As announced by the Office of Management and Budget, the document includes a new start-up program for the MGCO (Mars Geoscience Climatology Orbiter) mission. Mixed in with the set of encouraging figures of NASA's Space Science and Applications budget plan, unfortunately, is the more uncertain area of funding that includes support for the Research and Analysis program. These programs seem to be less vis-ible in the budget, but they include important components of the space science program. A large portion of these funds is provided to university scientists to support research at the highest levels of excellence.

In a recent letter to members of the academic scientific community, William L. Quaide, chief scientist of NASA's Solar System Exploration Division, expressed a note of uncertainty and caution about the fiscal year 1985 budget operating leel for the Research and Analysis programs. According to Quaide: "The reduction in (Research and Analysis) funds will require that we abandon, temporarily, plans to address all the problems that are facing us, and concentrate our support on a few specific areas to preserve somecontinuity of participation and to maintain continuity of participation and to maintain con-

pabilities for future missions."

Quaide pointed out that an augmentation of \$15 million will be needed to maintain the support level of funding realized by the fiscal 1984 appropriation. Indeed, an augmentation for the research and analysis program is included in the president's budget, but only in the amount of \$6 million. Conceivably that number could be increased by Congress if the need were made known—PMB

Titan Ocean: Ethane, Methane, Nitrogen

Detection of the atmosphere of Saturn's satellite Titan by the Voyager I spacerraft indicated an abundance of only 3 mol % methane (CH4). Recently J. I. Lunine, D. J. Stevenson; and Y. L. Yung calculated that 3 mol % methane is sufficiently low to proclude the stable coexistence of liquid methane on Titan's surface, which has a temperature of 94 K (Science, 222, 1229, 1983). Instead, Lunine et al. suggest that Than's apmospheric methane may have broken down by a catalyzed.

photochemical reaction to ethane (CgHo). The resulting ocean would consist of a mix-mire of CgHo and CHo in the proportion of 3 to 1.

The dissociation steps of Calla involve loss of hydrogen by escape, making the process irreversible. The postulated set reactions are: 2CH₄ → C₂H₆ + H₂ and 2CH₄ → C₂H₆ + 2H. The intermediate molecule Calla plays the role of catalysis and shielding of Calls from photolysis. C.H. is calculated as being broken down in Titan's atmosphere at a rate of 1.5 x 10¹⁰ cm⁻² s⁻¹. The evolved H and H₂ would leave the exosphere at rates of 5.5 x 10° and 7.2 x 10°cm² S⁻¹ respectively. The result is the production of an ethane-rich ocean of I kin depth. The composition of Titan's present ocean was deduced from calculations of the C.H.-CH., N2-CH., and N2-C2Ha binary systems. To be consistent with Voyager observations, it was noted that the existence of several percent propane in the ocean would be compatible with the calculatportions. The calculations also include a 100-200 km thick layer of solid CaHa on Titan's ocean floor.

Than's ocean floor.

What is lacking to make a case for an ethane-rich ocean is more observational data.

Lunine et al. note that important tests of the model are verification of the existence of CH clouds with the correct opacity, detection of C2Ha saturation of the lower troposphere, and radar evidence of an acean.—PMB

Alaskan Transect

A cooperative geophysical/geologic transect of the Alaskan crust and upper mantle is being organized by the U.S. Geological Survey (USGS), the Alaska Division of Geological and Geophysical Surveys (ADGGS), the University of Alaska, and Rice University. The project is to be known as the Trans-Alaska Lithosphere Investigation (TALI). The route of TALI lies along the north-south corridor of the trans-Alaska oil pipeline between Prudhoe Bay and Valdez and extends oilfshore across the Pacific and Arctic continental margins. The transect will Incorporate several supplementary profiles intersecting the primary route. TALI is envisaged as a coopdimated multidisciplinary effort among government, academic and Industry scientists and Institutions.

institutions.

To prepare a prospectus for the transect, a workshop will be held in Anchorage on May 29 prior in the meeting of the Selsmological Society of America and the Curdilleran Section of the Geological Society of America (May 30—June 1). The National Science Foundation is co-sponsoring the workshop. Some of the studies that will constitute important elements of TALI are under way or

will be untrated this year. Rio, University and the University of Alaska are engaged in a cooperative study of the kinematics of detormafrom in the Brooks Range, ADGGS and USGS will continue geologic mapping and investigations in various areas along or near the transect route. To help launch, fALL the USGS will start this summer its Trans-Alaska Crustal Transect (TACT) project to investigate the structure and evolution of the crust, using scismic refraction/reflection, geologic, gravity and magnetic techniques. The TACT project will begin along the southern onshore segment of the transect, between Valdez and the Alaska Range; several investigators from other institutions will be directly involved. Other institutions, including Cornell University (COCORP), Lamont-Doherty Geological Ob-servatory, and the University of Utah are exploring participation in TALI in 1985 and later years. The goal is to complete the transect by the end of this lecade.

Geologists and geophysicists interested in participating in TALI or the May workshop should contact: Robert Page, U.S. Geological Survey, Mail Stop 77, 345 Middleheld Rd., Menlo Park, CA 94025 (415-323-8111); or John Davies, Alaska Division of Geological and Geophysical Surveys (907-474-6166), or David Stone, University of Alaska (907-474-7622), both at the Geophysical Institute, University of Alaska, Fairbanks, AK 99701.

This news item was contributed by Rubert A. Page, who is with the U.S. Geological Survey, Mode Park CA 04025

Geophysicists

Two AGU members received Fullnight scholarships for 1983-1984: John R. Holloway, professor of chemistry at Arizona State University, will be working in Australia. Teh-Lung Ku, professor of geological sciences at the University of Southern California, will be working in France.

In Memorium

The following AGU members are recently deceased. Their AGU section all diation and year of joining AGU are shown:

faime Amorocho, 64. An AGU Fellow, Hydrology, joined 1952.

Grover B. Crisp, 43, on April 20, 1983. Geodesy, joined 1980.

Mahdi Salih Hantush, 63, on January 14, 1984. Hydrology, joined 1949.

Allen A. Jergius, 80. Seismology, joined

Jack H. Meek, 66, on October 12, 1983. Solar-Planetary Relationships, joined 1959. Heinz G. Poetaschke, 68, in November 1983. Geodesy, joined 1976.

The Boundary Integral **Equation Method for Porous Media Flow**

James A. Liggett and Phillip L.-F. Liu, Allen and Unwin, New York, 1983, xi + 255 pp.

Reviewed by Mary P. Anderson

Just as groundwater hydrologists are breathing sighs of relief after the exertions of learning the finite element method, a new technique has reared its nodes-the boundary integral equation method (BIEM) or the boundary equation method (BEM), as it is sometimes called. As Liggett and Liu put it in the oreface to The Boundary Integral Equation Method for Porous Media Flow, "Lately, the Boundary Integral Equation Method (BIEM) has emerged as a contender in the computation Derby." In fact, in July 1984, the 6th International Conference on Boundary Element Methods in Engineering will be held aboard the Queen Elizabeth II, en route from Southampton to New York. These conferences are sponsored by the Department of Civil Engincering at Southampton College (UK), whose members are proponents of BIEM. The conferences have teatured papers on applications of BIEM to all aspects of engineering, includ-ing flow through porous media. Published proceedings are available, as are rextbooks on application of BIEM to engineering prob-lems. There is even a 10-minute film on the

The applications of BILM to flow through porous media are explored by the other ma-jor proponents of this method in this text-book by Liggett and Liu of Cornell Universi-ty, Briefly, BIEM involves an application of Green's formula, which allows the dimensionality of a problem to be reduced. The method consists of placing nodes on the boundaries of the domain -- a line for 2-dimensional problems, an area for 3-dimensional problems—and integrating over the houndary. Then application of Green's formula makes it possible to solve for the head at any point in ... the interior of the domain. The catch is that it is necessary to know both heads and their normal derivatives along the boundary. Fortunately it is possible to derive an expression relating head along the boundary to its nor-

mal derivative, so that given either head or its derivative, it will be possible to solve for the other at each node. An advantage of the method is that any approximation involved in discretization is limited to the boundary, although there is a boundary layer effect causing heads near the boundary to be more subject to numerical errors than heads in the interior of the domain. Liggett and Liu suggest that the thickness of this boundary layer is approximately equal to the length of a boundary element.

The book is written at an advanced level and requires a thorough familiarity with calculus as well as the theory of flow through porous media and finite element techniques. lie examples used to illustrate the use of the BIEM reflect the training of the authors, in that classical engineering problems in flow through porous media are emphasized including flow through dams, flow around a cut-off wall, flow to wells, seepage from a pond, and recharge from circular and rectan-

A mathematically compact introductory chapter reviews the basic theory of flow through porous media and the relevant governing equations and serves to introduce the reader to the authors' notation. Chapter 2 describes the application of the method to simple problems involving Laplace's equation and linear interpolation of head between boundary nodes (linear boundary elements). Chapter 3 deals with more sophisticated interpolation schemes, known as special elements. Chapter 3 also introduces a powerful feature of the method, whereby infinite domains can be treated by using an analytical solution to construct a special element to extend the problem domain from the near-field solution, where a detailed solution is desired. out to infinity. In this way the problem of de-fining nearfield boundary conditions is avoid-

BIEM treats heterogeneity by dividing the problem domain into several homogeneous zones. The concept of zones and the equation manipulation (by stretching the coordinate system) required to treat anisotropy are discussed in Chapter 4. Chapter 5 describes the solution of transient free-surface problems using steady state governing equations and transient boundary conditions on the free surface. Chapter 6 deals with axial symmetric flow problems, including recharge from cir-cular areas and flow to wells. Chapter 7 deals with 3-dimensional solutions of Laplace's

equation applied to well problems and to unconfined aquifers using a transient boundary condition on the free surface. Chapter 8 discusses the application of BIEM to problems involving a sharp interface between two fluids, e.g., salt water intrusion without dispersion. Chapter 9 focuses on the intriguing way in which boundary elements can be combined with standard finite elements. It is clear that a finite element approximation is more appropriate for heterogeneous problems. However, if only a portion of the problem domain

is heterogeneous, it may be advantageous to

roblems, in which finite elements are used

for the unsaturated zone and boundary ele-

ments are used for a homogeneous saturated

of the BIEM are compared to analytical solu

tions and to results of finite difference and fi-

nite element solutions drawn from the litera-

Chapter 10, the longest in the book, dis-

cusses the application of BIEM to problems

involving regional groundwater basins includ-ing leaky aquifers. The problems are handled

using a quasi 3-dimensional approach, where-

horizontal and flow through confining beds is assumed to be vertical. Reference is made to

a computer code called GM5, which was used

to simulate the Yun-Lin aquifer in Taiwan.

Output from the simulation is presented but

the code is not, owing to space limitations. However, sample FORTRAN codes are pre-

sented in chapter 11. The code GM8 solves

the Laplace equation using linear elements; GM9 is an extension of GM8 that allows for

the use of special elements; and the program

through a dam of constant hydraulic conduc-

tivity. In addition to the codes, documenta-

put data sets are presented. An appendix

tion of input as well as sample input and out-

containing a list of symbols used in the book

The authors succeed in presenting a con-

vincing case for the utility of BIEM for cer-

ography gives only a few references on appli-

cations of BIEM to flow through porous me-

dia and these are largely papers by Liggett or Liu. Hence, one is left wondering why the

tain types of engineering problems in flow through porous media. Yet the book's bibli-

and discussion of some of the finer mathe-

matical points is also provided.

DAM solves transient free surface flow

by flow through aquifers is assumed to be

zone. Throughout chapters 2-9, the results

use boundary elements for the nonhetero-

geneous portion. Examples presented in

hapter 9 include unsaturated-saturated

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Mary P. Anderson is with the Department of Geology and Geophysics at the University of Wiscon-Madison, Madison, WI 53706.

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Edward Patrick, Publications Coor-

method seemingly has not caught on among specialists. The arsenal of mathematics needed to understand and program BIEM rivals the finite element method, and as a result BIEM is unlikely to take hold among "the masses" until the documentation and release of general "canned" programs similar to the one discussed in chapter 10. Still, the book is a good start in bringing BIEM to the attention of groundwater hydrologists and will be especially useful to those who already have a working knowledge of finite elements and who have occasion to solve those classes of problems for which BIEM is particularly suit-

Classified

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POSITIONS AVAILABLE

Program Manager Air-Sea Interaction. NASA Headquarters' Oceanic Processes Brain has seeking candidates for planning, developing and implementing a scientific research program unliving satellite techniques in the general area of an sea interaction. Specifically included is the use of satelline scattering that the content of the content rents. Our blications include: Habitis terramina care effectively. 2) demonstrated experience in road-ducing original rewards. As program management experience, and 4) knowledge of physical recomog-tagely. GS 13-15, with solary ranges from \$11,277 to For LLS, commenciate with experience-dimension. For first or distinct information is garding requirements and application presentative with to arbitras below or phone 2023-75-6687. For mid-applications must be received by Mac 6, 1984.

NASA Headsplanters, Code NHP, Washington, D.C., 905-16. An equal opportunity employe

Faculty Postation/UCLA. The Department of Facth and Space Sciences, UCLA seeks applications for a regular Loudy postation in the area of sedimentodogs, astungaphic, and regional geology. A Ph.D. or equivalent is required. There is no restriction as to the level. Dance will include undergraduate and graduate teaching, supervision of theses and dissertations, and development of a research program in the area of specialization. Field-hard experience will be taken into consider atom. The appointment will begin not later than January 1, 1985, and may begin as soon as July 3, 1985. It will be full-time, rangegraphy, tenure or tenure track. Send resume begin as work as July 1, 1981. It will be full-time, rime-worth, femule or femure track. Send resume to: Dr. William M. Kaula, Chairman, Department of Earth and Space Scences, University of California, 405 Higand Agence, Los Angeles, CA 90084. UCLA is an allumative action/equal opportunity

University of Colorado-Boulder—Tenure Track Position in Atmospheric Dynamics. The Department of Astrophysical, Planetary and Atmospheric Sciences (formerly Astro-Geophysica) invites applications for a tenure track Leathy position in the field of amospheric science. The successful applicant must have a Ph D degree and should prosess a strong background in geophysical fluid dynamics or dynamic interestically in modeling large scale terrestrial and/or planetary circulations. The application interestical and/or planetary circulations. The application will be at the assistant professor level follibough the assistant with the Laboratory for Atmospheric and Space Physics, which has ongoing programs of space observations of planetary atmospherics.

To apply, please send a currendium vita and the names and addresses of three references to:

Professor Gary E. Thomas
Department of Astrophysical, Planetary and Atmospheric Surfaces

Campus Box 391

University of Colorado

Roulder, CO 80 809

Telephone; 303-492-8913.

Telephone: 303-492-8913. Salary: \$24,000 magazum.

Salary: \$23,000 minimum.

Application deadline: Postmarked no later than March 15, 1984aLater applications will be accepted if the position is not fillerly.

The University of Colorado is an equal opportunuv affirmative action employer

Planetary Geologist/Geophysicisu Jet Propulsion Laboratory, Earth & Space Sciences Division. The Planetary and Oceanography Section anticipates the availability of one or two fulfitine, staff scientit research positions in the areas of planetary geology and geophysics. The rank of appaintment is open, but applicants should be beyond the postdoctoral level with a demonstrated record of expertise and accomplishments in independent research and publication. We welcome applicants with interest in structural geology and geophysics as applied to the study of while-body planets and ratural satellites with emphasis on determining surface properties and pine evec on planetary objects using ground-bose and spacecally remote sensing data and applicable theoretical and experimental techniques. Applicants should send letter outhing their experience, professional geals, resume, and copies of pertinent publications to: Dr. William R. Ward, Manager, Planethysy and Oceanography Sertion, Jet Propulsion Laborators, 4000 Ock Grave Dive, Dept. 154, Mad Stop 249-104, Pavadena, CA 91109. An equal opportunity employer mif.

An equal opportunits employer mil. Postdoctoral Position/Dalhousie University. A two-year position in the Oceanography Department is available for a person interested in marine geophysics. Specific work involves participation in heat flow audies across the margins of castern Canada but broader opponunities also exist for self-monivated projects within the University or at Bedford Institute of Oceanography. A Ph.D. in geophysics and desire in work 1-2 mostlyr at sea are required. Experience with heat flow helpful but not exential. Send C.V. and names of two references to: Dr. K. E. Louden, Dept. of Oceanography, Dalhousie University, Halifax, N.S. Canada, BSH 4]1.

Research Position in Space Plasma and Auroral Physics. Two research positions at the level of assistant or associate research scientists are available in the Department of Physics & Astronomy at the University of Iowa for qualified candidates with a Ph.D. degree and experience in space plasmas and/or auroral physics. Present research in space plasma physics emphasizes analysis and interpretation of observations of magnetospheric plasmas using instrumentation on board earth-orbiting spacecould in the IMP and ISEE Missions. The University of Iowa's global imaging instrumentation on the spacecraft Dynamics Explorer 1 is the source of an extensive data base of auroral images from high altitudes at visible and ultraviolet wavelengths. Photometric observations are also available for other areas of research including the physics of the upper atmosphere and the global distribution of atmospheric ozone. The applicant should identify and describe areas of his or her expertise which can support experimental or theoretical investigations in space plasma physics and/or auroral physics. Salary and position will be determined by the applicant's qualifications and experience.

A resume and the names of three persons beautifully and the careas of the page of the page of three persons beautiful to the page of the plasma physics and/or auroral physics. Salary and position will be determined by the applicant's qualifications and experience.

position will be determined by the applicant's quali-fications and experience.

A resume and the names of three persons knowl-edgeable of applicant's experience should be for-warded to: L. A. Frank, Department of Physics & Astronomy, University of Iowa, Van Allen Hall, Iowa City, Iowa 52242.

The University of Iowa is an affirmative action/ equal opportunity employer.

Geophysicist/University of Minnesota. The Department of Geology & Geophysics invites applications for a tenure track position in solid-earth geophysics beginning fall 1984. We seek a Ph.D. and preferably some postdoctoral experience. The field

preferably some postdoctoral experience. The field of interest is open but includes, for example, gravity/magnetics, global and regional tectonics and the physical state of the crust and mantle.

Present research programs in geophysics include geomagnetism and paleomagnetism, mineral physics at high pressures, and crustal seismology. We also emphasize the interconnectedness of geophysics with the in-house strong programs in auqueous and isotopic geochemistry, tectonics, and limnology. Please submit a letter of application and attach a curriculum vitae, statement of research and teaching interests, a list of publications and the names of three to live references by March 15, 1984 to: Subir Sanciec, Department of Geology and Geophysics, Minneapolis, MN 55455.

The University of Minnesota is an equal employment opportunity/affirmative action employer and encourages applications from qualified women and manorities.

Environmental Sciences Director. Growth opportunity to manage a division dedicated to environmental studies, technology development and mitigation, emphasizing innovative fossil energy recovery; Required is a PhD or equivalent plus 10 years related research and leadership/management accomplishment. Location in Rocky Mountains on University of Wyoming campus offers excellent quality of ille for the outdoor recreation, university, small community oriented. Send credential, reduding salary requirements to Manager of Personnel Services, WESTERN RESEARCH INSTITUTE; P.O. Box 3595, University Station, Laramie, WY 82071.

Symposium on Meteorology and Oceanography of North America High Latitudes. A Symposium of Meteorology and Oceanography of Northern High Latitudes will be held October 3–5, 1984, in Au-

Latitudes will be held October 3-5, 1984, in Auchorage, Alaska. The meeting will be cosponsored
by the American Meteorological Society and the
AAAS, and will be held in conjunction with the
Alaskan Science Conference.

Papers are solicited out all aspects of high latitude
meteorology and or canography, although the facus
will be on time scales ranging from less than a day
to secretal months. Sessions are planned on the following topics: alresea in cinteraction in the high latitudes of the North Pacilla; longrange forecasting
for the Alaskan region; meteorological aspects of alr
pollution in the Far North, with special emphasis on
the Fairbanks region; and the variability and predictability of sea ice conditions in Alaskan waters.
Papers describing results from the Bering Sea
MIZEX (Manginal Ice Zone Experiment) are encouraged.

couraged.
Abstracts of less than 200 words should be submitted by I April 1984 to Stuart Bigler, National Weather Service, 701 C Street, P.O. Box 28, Anchorage, Alaska 99513. Authors will be notified of acceptance of papers in early May.

University of South Alabama, Faculty Position. Tenure-track position at the tank of Assistant Professor in one of the two following fields: (1) Invertebrate Paleomology-Stratigraphy; (2) Igneous OR Metamorphic Petrology. The University of South Alabama has approximately 10,000 students, and is located in a growing metropolitan area. The Department of Geology and Geography has approximately 200 majors, and a faculty of nine full-time and three part-time members. This position is to be filled commencing September, 1984. The deadline for applications is May 15, 1984. Please submit letter of application, along with a resume of your education and experience, to: Dr. Glenn R. Sebastian, Chalrperson, Department of Geology and Geography, University of South Alabama, Mobile, AL. 36688. Also arrange to have at least three letters of reference sent to the same address.

The University of South Alabama is an equal opportunity, affirmative action employer.

Cosmochemistry Faculty Position/University of Arisons. The Department of Planetary Sciences and the Lunar and Planetary Laboratory invite applications for a state funded, tenure track position in Cosmochemistry. The area of specialization with in Cosmochemistry is open. The appointment in volves research, teaching, and the supervision of graduate students. The successful candidate will be graduate students. The successful candidate will be of scientific accomplishment, as well as the potential for developing substantial leadership capabilities of scientific accomplishment, as well as the potential of developing substantial leadership capabilities at a senior level having already demonstrated designations will be accepted at least until May 18; 1994 eations will be accepted at least until May 18; 1994 cations will be accepted at least until May 18; 1994 cations, including a resume and the named and addresses of four individuals who could serve as references, should be sent to: Professor, Eugente H. Levy, Head, Department of Planetary Sciences, University of Arlzona, Tucson, AZ 85721.

Research Associate. The Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado, Boulder, Colorado is advernisting for a Research Associate position. The posi-tion description is as fullows. The incumbent will be a state of the control of the cont ion description is as follows. The incumbent will initially participate as a member of a team of scientists in CIRFS and NOAA meoded in the development and Gallitation of two UV spectroadiometers for rocket-dight measurements of the solar UV spectral irradiance. This research is part of a program to determine the temporal variations of solar UV radiation, then stratospheric effects and possible effects on climate. The incumbent will participate in mountain-top measurements with the long-wavelength UV spectroradiometer to obtain direct intercomparisons at UV wavelengths with the wavelength UV spectroradiometer to obtain direct intercomparisons at UV wavelengths with the mountain-top solar spectral it radiance measurements in the near UV, visible and intraced in collaboration with the University of Arrizona. The mountent with the University of Arrizona. The mountent with the responsible for the integration of the UV spectroradiometers into a rocket payload induding developing the electronics interface, with duding developing the electronics interfaces with the sun-pointing system and the telemetry system. After the first rocket-flight measurements and de-After the first rocket-light measurements and de-pending on the experience of the incumbent, the accumbent's participation will range from a partici-pating member of a team to being in charge of the follow-on rocket experiments, including the launch-site expectitions, recallibrations, and originating pro-posals to government agencies for rocket-flight and reconsistsition subsets.

posals to government agencies for rocket-light and ground-station support.

The qualifications and desirable experience are as follows: a research scienust with a Ph.D. degree or equivalent in either physics, atmospheric science, astrophysics, meteorology, electrical or mechanical engineering with two years of research experience is required. Design and testing experience with electronics systems and microprocessors for use in the harsh environment of space, and for surviving the high-vibration environment of launch are required. high-vibration environment of Lunch are required. Experience in vacuum UV spectroscopy, radione-try, rocket-flight, balloon-flight, shuttle-flight or sat-ellite experiments or stratospheric research would be highly desirable. The salary range is \$23,000-\$50,000 depending on experience.

To apply for the position, applicants should sub-mit a letter and complete resume including publica-

mit a letter and complete resume including publications. In addation the applicant should request leters of recommendation from three individuals familiar with the applicant's personal and professional
qualifications for the product. All application material should be forwarded to: Dr. Robert F. Sievers,
Director, CIRES, Campus Box 449. University of
Colorado, Boulder, Colorado 80300, The closing
date for applications is April 15, 1984.

The University of Colorado is an affirmative action/enual outcommity employer.

Assistant Professor of Geophysics/Purdue University. The Department of Geosciences, Purdue University anticipates an opening for a new tenure track position at the assistant professor level in the area of explonation geophysics. The successful applicant must be prepared to assist in reaching exploration geophysics courses, advanced topics in his/her specialty and demonstrate an ability to develop and conduct productive research. Postdoctoral or industrial experience is desirable. The geophysics program in the Department of Geosciences at Purdue University currently consists of four full-time geopraints the performent of Geosciences at Purious University (urrently consists of four full-time geo-physics faculty. Field and laboratory equipment and ladities are available for applicanory to seismological and potential field geophysical methods. Excellent computing facilities including a Cyber 205 computer operated by Purche University and ministroniputers within the Department of Geosciences are available.

Send letter of application including brief description of research interest and goals, resume and

names of three references or:
Son W. Levandowski, Department of Geoscietors,
Purther University, Wost Lalavette, Indiana 47/07.
Glosing date for acceptance of application is May
L 1984 or until the position is filled.
Purdue University is an equal opportunity/affirmative action employer.

Physicist. The National Oceanic and Atmospheric Administration (NOAA) announces a Physicist. GS-13, vacancy in the Environmental Research Laboratories, Space Environment Laboratory, Supporting Research Division, Boulder, Colorado, Starting salary at GS-13 by el is \$50,152. Duties include conduction of the property of salary at GS-13 level is \$30,152. Duties include conducting research on the physics of the solar corona as related to the emission of matter and radiation which result in disturbances in the near-earth environment. Demonstrated achievement in boxic astrophysical research is required. For further into mation and application procedures, please rall Mary Plundey, NOAA Personnel at (303) 497-3102. Applications must be received by March 30, 1984, to be considered.

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University of New Mexico/Paleoniagnetism. The Department of Geology of The University of New Mexico incites applications for a tenure track full-time position as an Assistant Professor with a specialty in paleoniagnetism beginning Fall 1984. The successful andidate will be expected to maintain an active roserth program and much as the integral of the paleoniagnetic parts. active researli program and teach at the undergrad nate and graduate level. The Department has sixactive researt program and teach at the undergrau-tate and graduate level. The Department has six-teen full-time faculty, is located in a spectacular nat-tral setting and has excellent analytical facilities. Applicants should submit a resume, transcripts, and three letters of recommendation to R. Ewing, Department of Geology, Albuquerque, New Mexico 87 [31]. The deadline for applications is April 10, 1084

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Air Force Geophysics Laboratory Geophysica Scholar Program (1984–1985). The Air Force Geophysics Laboratory (AFGL) and The Southeastern Lemer for Electrical Engineering Education (SCEEE) announce that applications are invited for research appointments during the 1981–1985 year in the Geophysics Scholar Program. This program provides research opportunities of 10 to 12 months duration for selected Engineers and Scientists to perform research in residence at the AFGL, Hanstom AFB, near Boston, Massachuseus. Scholars will be selected primarily from such fields as Geophysics, Annospheric Physics, Meteorology, Ion Chemistry, Applied Science, Mathematical Modeling using Computers, and Engineering.

To be eligible, candidates must have a Ph.D. or equivalent experience in an appropriate technical

equivalent experience in an appropriate technical field. Some appointments may be confirmed prior to August 1984 so early applications are encouraged. All qualified applicants will receive consideration without regard to race, color, religion, sex, or national origin. Application Deadline for September Appointments: August 1, 1984. For further information and ambiguing forms contact SCFFF 1101 mation and application forms contact: SCEEE, 1101
Massachusetts Avenue, St. Cloud, FL 32769 Telephone: (305) 892-61-16.
SCEEE, supports Equal Opportunity/Allirmative

Faculty Position/Florida Atlantic University. The Physics Department is soliciting applications for an experimental physicist in a tenure line position at the Assistant Professor level beginning August,

Candidates must have a Ph.D. degree and have demonstrated a commitment to research and teaching. Preference will be given to candidates with

ing. Preference with the given to candidates which experience in experimental atmospheric physics, optics, or solid state physics.

Salary is negotiable. Deardline for applications—
April I, 1984. Contact Dr. Bjorn Lamborn, Chairman, Department of Physics, Florida Adamti, University, Bora Ranon, Fl. 33131, Tel (205) 293-3381.

Chairly Many Lamborn, it for a continuous and content of the continuous and content of the continuous and content of the conten Florida Atlantic University is an allumative ac-

Groundwater Hydrologist. Fullmine position Ph.D. in Civil Engineering or Coolydrology with one to five years experience or M.S. with eight to ten years experience, Dattes will consist of developing groundwater quadry research ideas, seek tunding and complete lunded proper Basic geolydrologic skills reputed with strong emphasys on chemical background, Modeling skills desirable. Applicant must demonstrate good oral and written communi-cation skills, be interested in developing own ideas and in assisting in staff judiagement, Send results for James P. Gibb. Flead, Groundwater Section, Blanos State Water Survey, Box 3020, Stanon V., Champangia, H. (1820–217-333-029)

The State of Illimov is an affirmative action/equal

University of Rochester/Postdoctoral Position in Low Temperature Geochemistry. The Department of Geological Sciences has a postulocional posterior for security on low-level, naturally occurring radioisotopes (Be-10, C.1-36, 1-129, etc.). The research involves the separation of trace amounts of these elements with emphasis on the measuremen of 1-129 in a variety of materials to evaluate its potential as a tracer for fluid movements. Measure-ments will be carried out on the University's tandem

accelerator.

The position is available immediately and is initially for one year with a possible one year extension. Send applications with resume and addresses

of three referees to: Dr. Udo Fehn Department of Geological Sciences University of Rochester Rochester, NY 14627.

The University of Rochester is an equal opportu-

physicist/Applied Mathematician, The Univer-of Tulsa.— The Departments of Geosciences Mathematics invite applications for an anticipatand Mathematics in the applications for an anticipated senior position with a joint appointment in both departments. A proven record of research and teaching in mathematical geophysis, and/or mathematical physics is required. Experience in exploration geophysics data processing is desirable. The closing date is March 15, 1984, Send vitae and letters of reference to:

Filward Douze, Chairman

Feward Doube, Chairman
Department of Geosciences
The University of Tulsa
100 South College
Tulsa, Oklabona 74104
The University of Tulsa has an equal opportunity/affirmative action program for students and employees.

Faculty Position/University of South Alabama. The Department of Geology and Geography is seeking to fill a tenure-track position at the Assistant Professor level, beginning September, 1984. Applicants should have major training and experience in geological application of remote sensing, and some phase of economic geology. The Ph.D. degree is required. This is a growing department with a present full-time faculty of tive geologists and for geographers and approximately 200 majors. Please send resume and arrange for three letters of reference to be sent to: Dr. Glenn R. Sebastian, Chairperson, Department of Geology and Geography, University of South Alabama, Mobile, Al. 3668. Applications should be sent before May 15, 1984.

The University of South Alabama is an equal opportunity, allumative action employer.

Physical Oceanography/Skidaway Institute of Oceanography. A physical uccanographer with a Ph.D. is being sought to conduct research on the continental shelf. Preference will be given candidate with a propriite in the particular statement. continental shelf. Preference will be given candi-dates with expertise in theoretical physical oceanog-raphy and who are interested in studying and mod-elling ocean-estuarine exchange processes antifor continental shell circulation. Such studies will com-plement and guide experimental programs present-ly being conducted at the Inwitute. The selected ap-plicant will be appointed at a level and salary com-mensurate with experience.

Interested persons are encouraged to submit a resume, the names of three individuals who can be contacted for reference purposes and a concise statement of research interests to: Dr. Jackson O. Blanton, (912)356-2457, Skidaway Institute of Oceanography, P.O. Box 13087, Savannah, GA 31416 before the deadline of March 30, 1984. The Skidaway Institute of Oceanography is an

Clay Mineralogy/University of Illinois at Urbana-Champaign. The Department of Geology invites applicants for a tenure-track faculty position in class mineralogy. We are seeking candidates who have clearly demonstrated the potential to be opparable. creats demonstrated the potential to be outdained researchers in the general areas of minerals, in the tallography and chemistry of clay minerals, in the origin, diagenesis, and metamorphism of argillaceous sediments and whose future research will consider a second or the metadoxisms. complement our existing programs in the petrology and diagenesis of sediments, experimental studies of compaction and of kinetics of birtial diagenesis, becompaction and of kinetics of burtal diagenests, be-havior of day innerals during deformation, petro-leum geology, and stable isotope geochemistrs. In addition to the development of a strong research program, the successful carelidate is expected to participate in all aspects of reaching and advising at the graduate and undergraduate levels. The Department of Geology houses a variety of facilities for day mineralogy research, including x-stay diffraction and fluorest ence units, an atomic ab-sorption specifically all the second control of the per-turbation of the photometer, two NMR spectrom-eters in participation and the mass spectrometers.

eters, an isotope-ratio mass spectrometer, and elec-tron microprobes. Numerous other analytical serv

tron microprobes. Numerous other analytical services are available or campus, particularly at the Materials Research Laboratory where there is equipment for Auger electron spectrometry, veray photoelectron spectrometry, varianting electron microgropy, mansussion electron microscopy, and ion microprobe studies.

This position is available immediately. PhD, is required. Rank and salary will be commensurate with experience and qualifications. For equal consideration, please submit a letter of application that includes a statement of current and future research interests as well as a curricultum vitae, hibblography and the names of at least 3 references willing to and the names of at least 3 references willing to comment on your qualifications and promise by April 1, 1984 to Dr. Albert V. Carozi, Chairman April 1, 1984 to Dr. Albert V. Carozzi, Chairman, Search Committee, Department of Geology, 245 Natural History Building, 1301 W. Green Street, Urbana, IL, 61801, Phone: 217/333-3008. The University of Illinois is an equal-opportunity affirmative action employer.

AGU **MEMBERS**

Moving? Call or write AGU with your change of address 6 weeks before your move.

Marine Geology and Geophysica/University of Washington. The School of Occanography is seeking candidates for a position as Research Assistant Professor, but applications at a more senior level will be considered. Preference will be given to a candidate who has research interests in marine geology and geophysics and who had be will interest in marine geology. didate who has research interests in marine geology and geophysics and who will interact with our ongoing research projects, especially in the area of ridge-crest processes. Although this position will eventually be funded through self-generated research grants, partial financial support is available for the first two years. Teaching requirements will be limited and at the graduate level. For consideration, send a resume, a brief letter describing research interests, and four letters of reference by I May 1984 to:

search interests, and four letters of reference by 1
May 1984 to:
Professor Brian T.R. Lewis
Director
School of Oceanography, WB-10
University of Washington
Scattle, WA 98195
The University of Washington is an affirmative

Postdoctoral Position/Atmospheric Chemistry. A postdoctoral position is available for a person with a Ph.D. degree in chemistry (preferrably analytical or physical) or micrometeorology. The position involves the measurement of atmospheric acidity and the dry deposition of trace gases from towers and aircraft. The successful applicant will be expected to travel to a variety of held sites and to perform chemical analyses using ion chromatography, A facility with computer programming, the labrication of tesearch equipment, and careful chemical contaminations outrod would all be useful. This is a two-year full-time position, with an ammad salary of \$15,000 during the first year, to begin in the summer of 1984. Interested persons should send a resume, names and phone numbers of three references, a statement of research interests, and any reprints to Barry Huebert, Department of Chemistry, Colonado College, Colonado Springs, CO 80002.

Colorado College is an equid opportunity employ-

STUDENT OPPORTUNITIES

Opportunity for Graduate Study in Igneous Petrology/Isotope Geochemistry—Southern Methodist University. The Department of Geological Sciences at Southern Methodist University in Dallas, Lexas seeks outstanding undividuals interested in a PhD seeks outstanding individuals interested in a PhD program in igneous periology aridon (surjoe geochemisty). The successful applicant should have a strong background in geology, chemistry, and mathematics and an interest in voltante processes. Research will involve participation in a field-oriented periological, geochemical, and coropa study of late Genezoic volcausity in the Chieny Andes For for their details and applications please contact either.

Dr. R. S. Harmon (214) 692-3075

Dr. M. A. Dungan (21 b 692-2752) Department of Geological Sciences Southern Methodist University Dallas, Texas 75275

State University of New York at Buffalo/Assistantship Opportunities. The Department of Geological Sciences mytics graduate applicants for Tall 1984. Graduate-Teaching assistantships ofter a stipend up to \$5,500,00 for 10 months, plus Indion waiver. Special assistantships in geophysics, geocheimstry-mineralogy, and glatiology carrying a 10-month stipend of \$7200,00 plus inition waiver are available. Additional summer support is possible Applications can be obtained from the Department of Geological Sciences, 4240 Ridge Lea. Amherst, NY 14226, 716-831-3051. Deadline for receipt of all materials is March 30, 1984.

The State University of New York at Buffalo is an affirmative action/equal opportunity employer and invites applications from minority and women candidates. No person in whatever relation with SUNYAB shall be subject to discrimination on the basis of age, color, national origin, race, religion, or sex.

AGU Congressional Selection Science Fellow: Midterm Report

Jack Fellows

As the recipient of the 1983-1984 AGU Congressional Science Fellowship (Eas, September 6, 1983, p. 543] I have been asked to report on my midterm experiences. I have learned two major aspects of business on Capitol Hill. First, I am impressed by the tre-mendously important relationship between science and the political world of Congress. Congressmen need and actively seek technical advice on legislative issues. As a scientist, one's point of view can have an impact on se

ciety as well as on one's discipline.

Second, I have been overwhelmed by the dedication of members of Congress and their staff. As in corporations and academia, the politics and bureaucracy can suffocate many good idea. However, considering these hings, plus overlapping committee jurisdictions and the inherently difficult legislative process, it is still a wonderment to meithat

Congress manages to produce anything.
The AGU Congressional Science Fellowship consists of four phases: selection, orientation, placement, and assignment. I would like to discuss each one of these phases: through each, I feel that I have learned and grown both personally and professionally.

Application required a letter of intent, vita, and letters of reference. Once short-listed, one wrote and presented a congressional briefing to a peer review board. I chose deepseabed mining as my topic; it offered me the opportunity to show my ability to research a briefing on (to me) a totally foreign topic.

Orientation

In addition to AGU, 19 professional societies enroll their Fellows in the AAAS Congressional sional Orientation Program. These societies include the AGU, ACS, APhA, NSPE, IEEE, and others. This year there were 42 Fellows, ranging in age from 28 to 50. All but 10 of the Fellows have their doctorate.

Fellows have been placed in Congress, OTA, and the State Department. Besides constantly tapping our Fellows network (the Fellowship) for legislation information, we have regular dinner and luncheon seminars and informal meetings. We set up our own seminars, which have so far included topics like Central America, ethics, the "gender gap," arms control, risk assessment, and lobbying. I have had the great pleasure of being the chairman of this year's Fellowship.

The goal of orientation is to prepare one for placement in the personal office of a member, on a committee staff, or in some other congressional branch. This program is a rather grueling sequence of congressional briefings from congressional agencies, members of Congress, committee staffs, historians,

others. In addition, there are meals and receptions with speakers, members of Congress, and congressional staff. The Fellows' friendship develops through this exhausting but thoroughly enjoyable "boot camp." The AAAS orientation is similar to the orientation that freshman congressmen undergo. By the end of the 2-week period, one has a better understanding of how Congress is structured, nate from Congress and slupe Congress. The contact with congressmen and staff makes one aware of the important "players" in Congress. Now was the time for placement.

AAAS representatives, former Fellows, and

Interviews

We were now let loose on Capitol Hill to find a position for a year. All the interesting aspects of congressional work we had heard about during the orientation made it very difficult to chose the appropriate member, commluce, subcommittee, or congressional branch. Prior to the orientation, I had chosen to work on hydrologically related issues. However, during orientation I had added to my list the areas of innovation, productivity, industrial policy, high-tech development, and

AAAS provided us with a room full of phones in the Senate Hart Office Building, a list of congressmen looking for Fellows, and interview comments from last year's Fellows. The AAAS leadership and support are indispensable to the success of this program. I left my condensed, one-page resume at

more than 30 offices. I eventually interviewed with 13 personal offices and 6 committees on both the Senate and House sides. I went back to many of these offices two or three times. There was a constant exchange of interview information through the Fellowship network and relatively little competition. We found out a lot about ourselves, Congress, legislative issues, and especially the underground tunnels interconnecting the congressional office

In spite of all my criteria for choosing an office in which to work, my choice rested very heavily upon office "chemistry." I chose to work in the personal office of Rep. George E. Brown, Jr. (D-Gal.).

Work

Besides being on the House Science and Technology Committee and the House Agricultural Committee, Rep. Brown has a personal interest in remote-sensing applications, water resources, and data base management, all of which I was involved in at the University of Maryland. Some of the other Fellows have told me that the members they work for do not even know their Fellow's name. I felt: quite fortunate in this respect, because I get a chance to talk with Rep. Brown frequently and I have accompanied him on hearings and speech trips.

For the first 2 months, 1 read congressional reports, attended meetings, hearings, and floor debutes and familiarized myself with

AQU (cont. on p. 78)

AGU Congressional Science Fellowship

The individual selected will spend a year on the staff of a congressional committee or a House or Senate member, advising on a wide range of scientific issues as they pertain to public policy questions.

Prospective applicants should have a broad background in science and be articulate, literate, flexible, and able to work well with people from diverse professional backgrounds. Prior experience in public policy is not necessary, although such experience and/or a demonstrable interest in applying science to the solution of public problems is desirable.

The fellowship carries with it a stipend of up to \$28,000, plus travel

Interested candidates should submit a letter of intent, a curriculum vitae, and three letters of recommendation to AGU. For further details, write Member Programs Division, American Geophysical Union, 2000 Florida Avenue, N.W., Washington, D.C. 20009 or telephone 462-6903 or 800-424-2488 outside the Washington, D.C., area.

Deadline: March 31, 1984

AGU (cont. from p.77)

congressional and office procedures. I was given industrial policy, space, information, and water resources policy as issue areas. was not given a specific project, except a speech on the role of the federal governm in science and technology. During this time I helped on office projects and constituent work. (The volume of letters, requests, and information coming in to a congressional office is staggering.) I attended Congressional Research Service programs to familiarize myself with the Library of Congress and its data

In November, Rep. Brown asked me to examine the possibility of drafting legislation for the commercialization of Landsat based on discipline resolutions and not the 80-m resolution of current proposals. I learned a great deal about possible suggestions at the National Telecommunications Conference and Jet Propulsion Laboratory.

However, after Congress adjourned in late November, I was asked to write four speeches on industrial policy, innovation, R&D, and ductivity topics. The Landsat proposal was shelved for a while.

During the recess Rep. Brown also asked me to examine an Office of Technology Assessment recommendation that the United States needed a National Center for Water Resources Research modeled after the suctessful National Center for Atmospheric Re-search. I have made some proposals for such a structure that have generated interest with Rep. Brown, members of the Interior Committee, and the National Association of State Universities and Land Grant Colleges. The timing may actually be correct for this legisla tion. A lot of politics and arrangements must be worked out before such a bill will be introduced. However, this legislation has now become my main focus. The chances are small

that it will make it to hearings before I leave. but I am endeavoring to lay the foundation I am enjoying the Hill very much. I know already it has had a great impact on my life. I know I will remain politically active when I return to the scientific community, and I would highly recommend this program to anyone regardless of profession or age.

AGU Membership Applications

Applications for membership have been received from the following individuals. The letter after the name denotes the proposed primary section affiliation.

Raffi Aroian (P), David Baker (P), D. Craig Barilotti (O), Stephen J. Barnes (V), Thomas O. Barnwell (H), Robert P. Bessette (G), Brian Bicknell (H), William Blumberg (A), Michele A. Boccadoro (G), Richard Boylan (T), Robert C. Bucknam (T), Roman J. Budzianowski (H), Bruce M. Crowe (V), Charles G. Cunningham (V).

Calvin R. Dunlap (O), David M. Farmer (O), Terry Fundak (G), Oswaldo Garcia (A), oises Garcia-Munoz (SC), Oktay Guven (H), Paul P. Hearn (H), K. V. Hodges (T), Kerry

F. Inman (T), Tom Intrator (SS). Richard Janda (H), Kathleen M. Johnson (V), Alan G. Jones (GP), Thierry Juteau (V), Peter Kearl (H), Tec Keith (V), W. J. Keith (V), Len Kobus (S), Randolph A. Koski (V),

Edward Laine (O), Kenneth K. Lajoie (T), Pasquale Lanciano (T), Timothy F. Lawton (T), James Leaird (S), Graig Lindberg (S), K. K. Liu (A), Mitchell W. Lyle (O), Peter Lysne

Ann Maest (V), Maureen Mahoney (V), Marangu Marete (H), Claire Max (SS), Linda McAdams (8), Anne McCormack (11), Thomas P. Miller (V), M. Daniel Morrison

Richard K. Nishunori (V), Tatsuki Ogino (SM), Giovanni Otsi (V), Srefano Otsini (SM), George A. Parks (H), Paul R. Passmore (St. J. P. Parel (GP), Jose M. Perez-Gorlov (II), James Robert Podolske (A), Benjamin L

Rice (1), James M. Roberts (A), David A. Seemann (O), Les E. Shephard (O), Andrew W. B. Siddans (D. Joel A. Silver (A), Stephen P. Smith (V), Claude James Sterling, R. N. Sudan (SS).

David J. Terrell (V), Robert H. Thomas (II). Yves M. Tourre (O), Michael Trainer (A), Faku Urabe (S), Jose Fco Valdes-Galicia (SC), Kunimiko Watanabe (SM), Lawrence Weiss (H).

Student Status

Jun Abrayano (V), Dave Boden (V), H. Herbert Breneman (SC), Mary F. Caress (V), Stefano Casotto (G). J. Vincent Eccles (A). Bruce Finney (O), Peter H. Gleick (A), Ann Isley (O), Sungtack Kwon (V), Jan Moxon, Kim Murphy (O), David W. Murray (O), Neil B. Myers (A).

Brian B. Quinn (S), Ingrid Reuber (T), Joseph Shields (SS), Carl L. Siefring (SA), Deborah K. Smith (1). Mary Streeter (8), Mohamed Sultan, Akiko Urabe (V), Ludovit Varga (SM), Jay D. Woosley (A).

AGU **MEMBERS**

Please write your member identification number on your check or money order to speed accurate processing by AGU.

Meetings

Announcements

Elevation Datums

Elevation datums are the subject of a 1-day program on March 13, 1984, at the annual meeting of the American Congress on Surveying and Mapping (ACSM) and the Ameri-can Society of Photogrammetry in Washington, D. C. Jointly sponsored by ACSM, the American Association for Geodetic Surveying, and AGU's Geodesy Section, the session will feature 11 papers. Registration for the session at member rates will apply to AGU members. For further information, contact Thomas J. Lauterborn, Rte. J. Box 127, Waterford, VA 22190, telephone 703-882-3334.

The paper titles and authors for the program are as follows:

Historical Overview of Vertical Datums, Herbert W. Stoughton

Geometrical Aspects of Vertical Datums, J. D. Buil, F. W. Young, and R. Mazanchi Defining Vertical Datums: What Is Zero?,

Aspects of a New Height System for North America, Sandford R. Holdahl

Fennoscandia Uplift, Plate Tectonics, and Seismicity, and Their Effects on Vertical Datums, Larry Brown

Definition: Oceanographic Approach, Bruce C. Dauglas and Robert E. Chanes The Determination of Geodetic Height From Laser Tracking Data, David E. Smith and

Demos C. Christodoulidis Deep Sea Techniques and Vertical Datums, William E. Curter

Gravimetric Approach to Defining Vertical Datums, Luman E. Wilcox NAVD 1988: A Status Report, Charles T.

The Administrative, Political, and Economic Aspects to Be Considered in the New Definition of the Vertical Datum, John D. Bossler

Geophysical Year

New Listings

June 11-12, 1984 Fifth European Conference on Environmental Pollution, Amsterdam. (V. M. Bhamager, Box 1779, Cornwall, Ontario K6H 5V7.)

July 5-6, 1984 Second Symposium on Plas-ma Double Layers and Related Topics, Innsbruck, Austria. (R. Schrittwieser, 1981. for Theoretical Physics, University of Innsbruck, Sillgasse 8, A-6020 Innsbruck, Austria.) (The deadline for registering is May

September 20-21, 1984 International Symposium on Environmental Pollution, Site To Be Announced. (V. M. Bhatnager, Box 1779, Cornwall, Ontario K6H 5V7.)

September 24-26, 1984 International Water Well Exposition, Las Vegas, Nevada. Sponsor, National Water Well Association. (National Water Well Association, 500 W. Wilson Bridge Rd., Worthington, OH 43085; iel.: 614-846-9355.)

October 10-12, 1984 Seismological Society of America Eastern Section 56th Annual Meeting, St. Louis, Mo. (Robert B. Herrmann, Department of Earth and Atmospheric Sciences, St. Louis University, P.O. Box 8099, St. Louis, MO 63156; tel.:314-658-3120.)(Abstract deadline is September

November 1984 Mexican Geophysical Union Annual Meeting, La Paz, Baja California Sur, Mexico. (Union Geofisica Mexicana, A.C., Comite Organizador Reunion 1984, Apartado Postal 1805, Ensenada 22800. B.C.N. Mexico.)(Abstract deadline is August 1.)

April 9-11, 1985 Fifth Annual Front Range Branch Hydrology Days, Fort Collins, Colo. (11. J. Morel-Seytoux, Dept. of Civil Engineering, Colo. St. Univ., Fort Collins, CO 80523; tel.: 303-491-5448 or 8549.) June 26–28, 1985 U.S. Symposium on Rock

Mechanics, Rapid City, S. D. Sponsor, South Dakota School of Mines and Technology. (Eileen Ashworth, Chairman, 26th U.S. Symposium on Rock Mechanics, Department of Mining Engineering, South Dakota School of Mines and Technology. Rapid City, SD 57701-3995; rel.: 605-394-2344.)

August 19-30, 1985 23rd General Assembly of IASPEL Tokyo, Japan. (Ryosuke Sato, Secretary General of the 23rd General Assembly of IASPEI, c/o Inter Group Corp., Akasaka Yamakatsu Bldg., 8-5-32, Akasaka, Minato-ku, Tokyo 107, Japan: tel.: Tokyo (03) 479-5311.)

The Geophysical Year calendar last appeared in the December 6, 1983, issue.

Richard H. Rapp

Separates

To Order: The order number can be found at the end of each abstract; use all digits when ordering. Only papers with order numbers are available from AGU. Cost: \$3.50 for the first article and \$1.00. for each additional acticle in the same order Payment must accompany order De-

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Geochemistry

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NO. 31 AND RESE SYSTEMATICS IN VOLCANICS AND DISTRIBUTE SEVALUPIS FROM MALAITA, SOLDMON ISLANDS, AND THE RATTER OF THE OSCING MAYA PLATERS IN Biclate-Evaluit, G. J. Wesserburg (Division of Garingias) and Planetary Sciences, California (Institute of Technology, Passicus, California (1125) and P. W. Winni

of Technology, Passions, California Silest and A. B. Ye. A. Many.

A B. Ye. A. Short and violic best fools and basels from Malaita, the Colosos Felands. The roughts shot the presence of relatively underfoord caule segments underlying older depleted mattle. The aloiten the three deals ratio best important and a basels widther deals ratio best important as a fact that a relatively undepleted mattle. It is dusarested that a relatively undepleted mattle magnetic that a fact and include in a large depleted is a fact that a start in the aloite has taffithed, indicating a Large depleted is a large that it is that the aloite has the content of the include in the along that continued anion and from those sources but ray be a thoroughly maintend and untime of this continued at the state and depleted under a mercan definition of the state and depleted under a mercan definition of the state and depleted until (991) or a segment of whom a continuated struct with appropriate latent and depleted until (991) or a segment of whom a continuated struct with appropriate latent and depleted until (991) or a segment of whom a continuated struct with appropriate latent and application in the segment of whom a continuated struct with a parapriate latent and application in the segment of whom a sub-interior to be for the late.

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Geodesy and Gravity

1999 General (Spherical Harmonic Techniques) THE EFFECT OF COORDINATE SYSTEM ANTATIONS ON SPHERICAL HARMONIC EMPANSIONS A NUMERICAL METHOD

SPHERICAL PARAMONIC EXPANSIONS A NUMERICAL TRIBO J. D. GOLISTEIN (The Analytic Sciences Corp. J. J. Golistein (The Analytic Sciences Corp. J. J. Golistein (The Analytic Sciences Corp. A nutaritis) cathod is presented for effecting the transformation of a spherical homonic expansion under an arbitrary fotation of the coordinate system. Included are results of numerical tests with expansions to degree and other is the standard of the figure of the algorithm. (Spherical high harmonics, rotations, numerical methods). J. Gerbys, Ras., B. Paper sholes.

Geomagnetism and Paleomagnetism

2599 General
DOMAIN WALL NUCLEATION AS A CONTROLLING FACTOR IN THE
BERMYIOUR OF FIRE MAGNETIC PARTICLES IN ROCKS
J. R. Boyd. N. Fuller (Department of Geological
Sciences, University of California, Santa Barbara,
California 93106) and S. Majoedahl
Difficulties in domain wall nucleation have been shown
to affect the domain state of the fine magnetic
particles in rocks. Particles, large enough to contain
a domain wall, remain saturated in rememence and only
nucleate an wall when a backfield is applied. In this
cycles and cycles through the law temperature anisourcept transition in magnetite. It is suggested that
in the pteudosingle domain grain size range can be
attributed to the increasing difficulty with which
walls are nucleated, as particle size decreases.
Geophye. Ram. Liett., Paper 440013 Coophys. Res. Lett., Paper 4L0013

Hydrology

High Contral (Hydrology)

SUPFACT INFICTATION IS SALT MARSHES! THEORY, MEABBRENEY

AND BIOSPICHEMICAL HOPLICATIONS

Harold F. Micrord Operations of Civil Engineering,

Harsachusetts Inscitute of Technology, Cambridge, Ma. 6;

Hilliam R. Muttle, Roger M. Burke, Ealth D. Stollambach

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and in the surface of the malt marsh dering tidal inundatif

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chemical types of altregum, carbon, and sulfur compount

Mater. Besour. Res., Paper 44065.

Water Reser, Res., Paper 440051

3199 General
UN THE PROBLEM OF PERMISSIBLE COVARIANCE AND
VARIDGEAN MORES
G. Christadors (4 Problemon St., Kellatson Sq.,
Athens, 617, Greene)
The covariance and variagean gudels (ordinary or
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worked and the proposition of the problemon of the proposition of the proposition of the problemon of the proposition of the problemon of the proposition of the problemon of the proposition of the propositi warlous oat lenting and similation techniques, which have been tocantly applied to diverse hydrologic problems. The present article provides the means of those techniques with convenient criteris to judge whether a function which artises in a particular problem, and is not included among the known covariants or variegram models, is permissible as such a model. This is done, by investigating the properties of the candidate model in both the space and fraquetcy domains, and covers stationary random functions as well as mose interesting classes of pon-stationary random functions. After the theory test as some interesting the thought is a support to the functions. After the theoretical support to the criteria testing the parming bility has been eatablished, we develop procedures to perfore this testing in a more practical context. We ampley attenting in a more practical context. We ampley the testing in the parentially transfer the stermological equations that sementially transfer macter in the one-dimensional space, together with approximations in towns of polygonal functions and Fourier-Ressol series expansions. Numerous examples

Meteorology

3720 Climatology

3720 Climatology
ON THE VAPIABILITY OF THE NET LONG-MAVE HARIATION
AT THE OLDAN SURFACE
1. Long 16:1.5.5. 2880 Brondway, New York. N.J.
10025), D.L. Unitison, and A. Lacia
The built formulae 189; commonly used to estigate
the new longwave rediction at the ocean surface
(LMM) often alve dissimilar remains for given surface parameters. Because the difference are climstocyglically symiftered amounts of energy is to
theory and to understand the sources of classe differonces. We predent an evaluation of the most,
wheley used Bt. In terms of the assimptions made
in each, the climatic conditions on which each ip
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results computed from the full realistive transfer
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The differences can beat be understood through,
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ture, hamility and cloud properties in the mossibilities reveal that under clear six conditions reveal that under clear six conditions, to around a deviation perturbations of either temperature of specific burdlity in the strepheric column above the surface laver can improduce the certainers of as in kind, these early long, which sould be typed of the sungitive articles are the certainers of the results green typed of the sungitive article that the differences produced by using different P for the same surface conditions. Withough the difference between B Lam and RH Tay can be large, the results from the herlind and indexage formulae duplicate the RH sizes six that is the formulae duplicate and conditions. dicions. The RTI studies also reseal that its sariations

The RT studies also reveal that the variations due to cloudliness effects can be very large. Its clouds can reduce the first their sky whiles by as much as 70 M/m², there is strong dependency of the on the vertical distribution of cloud properties which renders macless, for estimating instances, to extend the contract of the R shich do not carefully distribution shies, the R shich do not carefully distribution shies, the R shich do not carefully distribution shies, the planting of the second the associated shifted information about the geographic and temperal distributions of cloud properties.

The computed sensitivity of the to cartations in the stonespheric column litustrates the type of information and the level of accuracy in the proved renote sensing techniques and improved unformation about the cloud distribution statistic parameterization of cloud effects in the Hadiation, surface energy budget, clouds). budget, clouds). Rev. Geophys. Space Phys., Paper 4R0239

3720 Climatology EFFECTS OF DYNAMICAL HEAT FLUXES ON MODEL CLIMATE BENSITIVITY EFFECTS OF DYNAMICAL HEAT FLURES ON MODEL CLIMATE SEMISITY TY
W.-C. Mang (Atmospheric and Environments Research, loc., Cambridge, MA 02139), 0. Molnar and T. P. Mitchell, and P. H. Stone (Canter for Metaorology and Physical Genengraphy, MIT, Cambridge, MA 02139)
The effect of the maridiomal and vertical dynamical hast fluxes on climate sensitivity is investigated using an ammal mean coupled high and low latitude redictive-dynamical model of the Northern Hamisphere. The model was constructed by Incorporating a seridional (atmosphere and ocean) dynamical heat, flux parameterisation into a two-tone (low latitude 0-10W and high latitude 10-90W) werelon of the vertical addactive-convective model. The atmospheric vertical dynamical heat flux is persenterised through the convective adjustment with two critical lapse rates - the motat adiabatic lapse race and the critical value for baroclimic adjustment. The maridional dynamical hast flux is related to the meridional temperature gradient supplically. Cloud covers and altitudes and relative empirically. Cloud covers and altitudes and relative hamidity are fixed. Ice albedo-temperature feedback

inclused. The feedback in the dynamical hast fluxes is found to produce a strong stabilising effect on climate. The warming of the hesispheric mean surface temperature induced by a 2% increase in solar constant and a doubling of carbon dioxide concentration could be increased by se such as a factor of a if the feedbacks increased by as such as a factor of a if the feedbacks from the waridional and vertical dynamical heat fluxes were both eliminated. The coupling effect of the vertical and maridional heat fluxes is a law calculated to a very strong, i.e., the vertical flux feedback is atrougly stabilizing in the presence of moridional flux feedback, but descrabilizing in the presence. In fact, the model's current climate is unstable in the letter case.

The interactions of the dynamical hear flur with other temperature-dependent feedbacks such as radiation, ice albeds and humidity, and their subsequent affects on climate are also studied. (Climate sensitivity, Dynamical heat flures)
J. Goophya. Res., D. Paper 400233

Oceanography

4713 Circulation MEAN CIRCULATION AND PLAY KINSTIP ENTROY IN THE SACTEDI ACRIDI ATLACTIC

W. Krauss (Institut Für Mooreskande, 25-km), Contemporation Mag 20, Company), R.B. Kiret2 satellice-tracked buoys have been released in the northern part of the sectors and control Borth Atlantic during 1931 and 1982 by the Institut Cir-Recreshands, Alel. Additionally, blocky seployed In spring 1980 by the Bedford Institute town teen taken over. Mean values and variouses about the mean have been calculated for to by to areas. The nounvelocities confirm the large-conic pyro electionical es deduced from hydrographic data and numerical models. The centre of the gave to becated at about Will, tally

J. Goophym. Rem., A. Paper 4A0227

AN EMEGY PRINCIPLE FOR MICH-LATITUDE ELECTRODYRAMICS
D.D. Barbase (Institute of Geophysics and Flanstary
Physics, UCLA, Los Angoles, CA 90022)
A theoretical modal for aid—and high-latitude electric fields and currents is constructed using Fourier
analysis mathods. A two-diseastions) plans loneaghere
with an enhanced conductivity surcoral belt and fieldmigned currents at the edges is imployed. The postulate that the electric field and currents adjust selfconsistently to minimize the global Joule dissipation
rate defines a theoretical relation between the primary and secondary field-aligned currents. This socalled minimal dissipation configuration is examined
using several input field-aligned current models and
graphical solutions for the electric field and ionoaphoric current are shown. A detailed discussion and

Journal of Geophysical Research

Volume 89 Number A3 March 1, 1984

New Empirical Models of the Electron Temperature and Density in the Venus Ionosphere With Application to Transferminator Plany (Paper 3A 1842) Three-Dimensional Ray Trucing of the Jovian Magnetosphere in the Low-Troquency Range (Paper 3A1903)

J. D. Menletti, J. L. Green, S. Guikis, and F. Six

Aperiodic fon Temperature Variations in the lo Plasma Torus (Paper 3A1838) Correlation Between the He/H Ratios in Upstream Particle Events and in the Solar Wind (Paper 3A 1944) M. S. holer F. M. Ipavich, J. T. Gusting, and M. S. holer Magnetopause Structure and the Question of Particle Accessibility (Paper 3A 1921).

The 40-keV Blocker D. D. Martin R. L. Constant Particle Accessibility (Paper 3A 1921). The 40-keV Electron Durable Trapping Region (Paper 3A1627)

The Radial Distribution of Radiation Belt Protons: Approximate Solution of the Steady Stole Transport Equation by Arbitrary Pitch Angle (Paper 3A1708)

V. Jentsch

intensity and Polarization Characteristics of Whistiers Deduced From Multi-Station Observations (Paper 3A1819)

E. W. Paschal and R. A. Heilhreit E. W. Paschal and R. A. Heilhreit E. W. Paschal and R. Tsaruda

S. Machida and R. Tsaruda

E. J. Weber, J. Bigchan, J. O. Moore, J. R. Sharber, R. C. Livingston, J. D. Winningham, and B. W. Reinisch

Dayside Aurural Dynamics (Paper 3A1637)

R. II. Eather

Prediction of Photon Yields for Proton Aurorae in an N2 Almosphere (Paper 3A1685)

B. Van Zyl, M. W. Gealy; and II. Neumann

S. Nama Zyl, M. W. Gealy; and II. Neumann

B. Van Zyl, M. W. Gealy; and II. Neumann

Variations With Geomagnetic Activity (Paper 3A1753).

R. II. Bather

B. Van Zyl, M. W. Gealy; and II. Neumann

B. Van Zyl, M. W. Gealy; and II. Neumann

B. Van Zyl, M. W. Gealy; and II. Neumann

B. Van Zyl, M. W. Gealy; and II. Neumann

B. Van Zyl, M. W. Gealy; and II. Neumann

B. Van Zyl, M. W. Gealy; and II. Neumann

The Clobal Distribution of Theoremset. Chapter 3A.1752)

II. G. James, R. L. Dowden, M. T. Rietvold, P. Stubbe, and II. Kopka

Phase Measurements of Whistier Mode Signals From the Siple VLF Transmitter (Paper 3A.1941)

E. W. Paschal and R. A. Hellincil

Intensity and Polarization Characteristics of Whistiers Deduced From Multi-Station Observations (Paper 3A.1819)

F. Layer (onjugation Detached to the Color of Multi-Station Observations).

The Global Distribution of Thermospheric Odd Nitrogen for Solstice Conditions During Solar Cycle
Minimum (Paper 3A1751)

J.C. Gérard, R. G. Roble, D. W. Rusch, and A. I. Stewart

J.C. Gérard, R. G. Roble, D. W. Rusch, and A. I. Stewart

1727 AND ISSE 2 OBSERVATIONS

1728 AND ISSE 2 OBSERVATIONS

Patterns of Potential Magnetic Fleid Merging Sites on the Dayilde Magnetopause (Faper JA1904).

Patterns of Potential Magnetic Fleid Merging Sites on the Dayilde Magnetopause (Faper JA1904).

App Dependence of Auroral Zone Fleid-Aligned Current Intensity (Paper JA1702)

Bands of Ions and Augular V's: A Conjugate Manifestation of Ionospheric Ion Acceleration (Paper JA1926).

Optical Mapping of Ionospheric Conductance (Paper JA1874).

Color Plates

J. D. Wijningham, J. L. Burch, and R. A. Frahm

Color Plates

J. D. Wijningham, J. L. Burch, and R. A. Robinson

S. B. Mende: R. H. Father, M. H. Reet, R. R. Voidtak, and R. M. Robinson

Total Constructions against control intensity of the planar shaet. The wave against control intensity of the planar shaet. The wave against control intensity of the planar shaet. The planar shaet into the manured inner boundary of the planar shaet. The wave against control intensity in the planar shaet into the manured inner boundary of the planar shaet. The planar shaet into the manured inner boundary of the planar shaet. The wave against control intensity in the planar shaet into the manured inner boundary of the planar shaet. The primarily the transverse magnetic control intensity in the planar shaet. The primarily the transverse magnetic control intensity in the planar shaet. The primarily the transverse magnetic control intensity in the planar shaet. The primarily the transverse magnetic control intensity in the planar shaet. The primarily the transverse magnetic control intensity in the planar shaet. The primarily the transverse magnetic control intensity in the planar shaet. The primarily the transverse magnetic control intensity.

The planar shape is the planar shape in the planar sh

kinetic contry decreases wast- and contragre and le contentrated along the forth Atlantic Current. It of cars that the North Atlantic Current (Bolze French In the columnature of eddy bloatic energy for the northern Borth Atlantic, whereas the Mid-Atlantic hidge to be source of eddy energy. Budy kinetic charge them forth Atlantic Current Jourseses trum about 1000 cast see mean fles. Fo avitant to 300 of n west of Costland, Alexagene .. paol of les edgy. Elizable energy (less than 100 cm' 5 ") missur in the central Earth Atlantic cast of the Mid-Atlantic Kidge. The level increases towards the Engagedraud African shelf was the mean scattered flow also become str nyer. The results exhibit the opportunent, (At-Dantic, West Circulation, delfting twoyse. J. Geophys. Res., C.Paper 400154

4765 Burfaco Waves, tides and see level APPLICATION OF A BIMPLE NUMERICAL WAVE PREDICTION HODEL TO LAYE ERIK

David J. Schweb (Great Leves Environmental Research Laboratory, KOAA, 2300 Vashtenay Avs., Ann Arbor, Ml. 48104), John K. Bennett, Paul C. Liu, and Matk A.

J. Goophys. Res., A, Paper 3A1874

5510 Bigh-latitude lonospheric currents
ISE-1 AND -2 OBSERVATICES OF AS USCILLATING CUTWARD
MOVING UNDERSI SHEET HEAR HIDDIGHT
T. J. Maily (Accompheric Ediences Department, University
of California, Los Angeles, California, 90024), C. T.
Pussell and F. J. Maiker
An outward moving current sheet is enamined with the
ISE-1 and -2 capactoacters. It is found that the
current sheet is moving outwards with a velocity of
about 17 ka/sac, a thicknows of shout 100 km, and with
the current flowing into the lonosphere. Uscillations
observed in the magnetic field profits indicate the
presence of a wave travaling along the current sheet
from midnight towards the seat with a velocity of 600
km/sac. The oscillations of the plants normal to the
current sheet associated with this wave are sufficient
to explain the amplitude of the clocity field oscillations in the plane of the current sheet observed by
the UCB electric field detector. In addition a strong
electric field is observed normal to the abect, fortroappending to a flow along the sheet of 600 km/suc, which
is consistent with the volucity of the wave adduced
from the intersatellite timing of the oscillations. Thus
the wave is arationary in the frace of the current
shoot places. This oscillating current wheat model
explains the observed behavior of both the magnetic and
electric field observations. The potential drup across
the current sheet was very large at this time, 41±2h by,
and is comparable to the total normal potential A parametric dynamical wave prediction model has been sdapted and tosted against semianalytic empirical results for steady conditions in a circular besin and excessive field measurements of wave hight, period, and direction. The adapted numerical model accurately predicts the directional spaceding of waves for uniform steady wind prodicted smallytically for fetching the steady wind prodicted smallytically for fetching the steady wind prodicted smallytically for fetching the said of the second compared to the cantral basin of Lake Zris and the results compared to observations of wave height and period (at two points in the labe) and direction (at one point), results for wave height and direction attactors were excellent compared to measurements at a research towor off the southern shore, but computed wave heights were lower than observed at a weather booy in the western part. The model escusions underserizated wave periods at both places. Thus, with locally measured wind data as input, the model escitates wave height and direction well and wave period greenedly. well and wave period occeptably. J. Geophys. Res., C. Paper 400201

Particles and Fields— Interplanetary Space

5310 Cosmic Pays (Solar Modulation)

SOLAR MODULATION OF COSMIC RAY ELECTRONS 1978-1983

Paul Evenson (Bartol Rassarch Foundation, University of Dalawara, Newart, DE 197111, and Peter Meyer.

The 19EE-1 spaceraft has provided over four years of continuous data from nearby interplanetary space, 8y using classe data together with pre-launch calibration dats and precise electron spacers from balloon flights in 1979 and 1982 at Thompson, Manteoba, Connada me monitor the flux level of approximately i UsY tosmic ray slactrons with one wonth time resolution. The steplie ougst of modulation observed for positive particles in 1979 is also seen in electrons confirming that the dociment modulation machanism is not mentioned to the charge of the particle. Newtreets effects observed in the previous solar manisms by Burger and Swannburg (1973) are not reproduced at the present solar manisms. A return to the relativity higher electron/proton ratics of the 1960's is a scrung possibility. Conclusions must be drawn with caution, however, elice the overall time structure of the present solar maximum is nightificantly different from that of the previous one. (Commic ray, electrons, solar medulation, gradient and curvature driften).

Particles and Fields— Ionosphere

5520 Electric (1elds An energy principle for high-latitude electrodynamics

A noninced theory of the Payloigh-Taylor instability which includes the effect of a transverse volectly shoar is prescuted. A two field model is used to describe an inhomogeneous plants under the influence of gravity and sheared equilibrium flow velocity, and to derive a differential equation describing the generalized Rayleigh-Taylor instability. An extensive parametric study is made in the collisionless and callstoned regimes, and the corresponding disportanceurves are presented. The results are applied to the equatorial fregion and to barium releases in the inneaphere. (Gravity, shear, Spread F).

J. Geophya. Res., A, Faper 4A0128 Particles and Fields— Magnetosphere

1.508

1517

S715 Electric Fields
RELATIONSHIP OF DUSF SECTOR RADIAL FLECTRIC FIELD TO
ENERGY DISPERSION AT THE INNER EDGE OF THE ELECTRON
FLASNA SHEET
J. L. Horwitz (Physics Department, The University of
Alabama in Bunteville, Hunteville, Alabama 35899)
It is shown that, assuming conditions of
approximate steady state and that the low-to-medium
electrons forming the plasmes sheet inner edge
originate from a source in the magnatotall, the
radial electric field in the dusk sector cam be
related to the radial energy dispersion of the plasma
sheet inner boundary as

the current sheet was own, large at this time, 41-24 by, and is comparable to the total mernal potential drop across the polar cap. (field-slighed corrent, electrostatic shock, electric field, electric potential drop).

J. Geophys. Res., A, Paper 440223

5580 Maye Propagation
NUMBERCAL SIMULATIONS OF INTERSITY SCINTILIATION USING
THE POWER LAW PHASE SCREEN MODEL
C. L. Pipo 1841to Physics Laboratory, SPI International
133 Rayanawood Avanua, Monito Park, CA 94024), I, Owen
Simulations of radio-wave acontiliation in power-law

Simulations of radio-wave actntilitation to power-law modia were performed to study the attracture of the intensity and phase spectra when the Freamel radius is much smaller than the outer scale or the low-frequency limit of the power-law region in the tin-situ irregularity spectrum. The results werify the critical dependence of intensity scintilation on the power-law indees pradicted by both asymptotic and more recent findings, the scintilitation characteristics of propagation in media characteristed by a two-component power law worm also recorded. The enterior state of the control o

ings, the activitiation characteristics of propagation in media characterisal by a two-component power law were also investigated. The results reconcile the interpretation of activitiation data from the Mi-leband satellite which showed a shellow sloped power-law phase spactrum with more recent intensity weingillation, data. (Scintillation, innospheric irregularities). Rad. Sci., Paper 49/231 556.

5599 General (Equatorial Spread F)
RAYIFIGH-TAYLOR INSTABILITY IN THE PPFICECE OF A
BYRATIFIFD SHEAK LAYER
P. Setymarayana (Science Applications, Inc., McLant,
Virginia 22102), P.N. Guzdar, J.D. Huba and S.I.

where (N,) represents the energy of the electron inner boundary. As increasing electric field component with radial electrics obtained from recent maturements of places sheet inner edge

Arbitrary Pitch Angle (Paper 3A1708)

Streaming Reversal of Energetic Particles in the Magnetolail During a Substorm (Paper 3A1892)

The Plasma Sheet Boundary Layer (Paper Al1689)

E. Eastman, L. A. Frank, W. K. Peterson, and W. Lemantsson
The Structure of the Plasma Sheet-Lobe Boundary in the Earth's Magnetolail (Paper 3A1480)

Election Density and Plasmapause Characteristics at 6.6 Rp: A Statistical Study of the OEOS 2 Rehaution Sounder
Data (Paper 3A1899)

Bernard Higel and Wa Lel
On the Relationship Between Morning Sector Irregular Magnetic Pulsations and Field-Allaged
Currents (Paper 3A1899)

Bernard Higel and Wa Lel
Othal Gloophie Current Distributions During Substorms (Paper 3A1889)

Chartents (Paper 3A1975)

At. J. Engebresson, L. J. Cahill, Jr., T. A. Paterna, L. J. Zanetti, R. L. Arnoldy, S. B. Mende, and T. J. Rosenberg
Chical Gloophie Current Distributions During Substorms (Paper 3A1889)

O. de la Beonjardiere and R. A. Heelts
Chertostatic Hydrogen-Cyclotron Wave Emission Below the Hydro

 $E \in \mathcal{T}$

interpretation of the solutions with teletion to di-verse observations and high-incitude phenomenology are included. (Electric fields, electric currents, icho-J. Goophys. No., A., Paper 4,0225

\$330 High Latitude ionospheric currents
OPTICAL MAPPING OF IONOSPHERIC computivities

\$3. B. Hende (Inchheed Paio Alto Remearch Laboratory,
\$3.251 Banover Stroat, Palo Alto, California 94304; R. R.
Rither, H. B. Pee, R. R. Wondrak, and W. W. Pohinson
Ionospheric Hall and Pedersen conductances are derived
from auroral apertocopic nessurements obtained with
teridian seanning photoseters. Conductances are also
derived from height profiles of electron density
obtained with the Incoherent scatter radar at Chafanika
in a coordinated experiment aimed at comparing the two
techniques. While general agreement is obtained by
using those basically different exchade, the
disagreeconts illustrate the advantance and liettations
of each experimental technique. The radar visids
Accurate values of conductance with limited temporal and
spatial resolution while the optical measurements
provide loss accurate values at high time sessibution and
over large regions of space. (ionospheric currents,
surorae, electric fields, particle precipitation).

J. Goophys. Res., A. Paper 341874

J. Geophys. N. g., A, Paper 440245

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local geometric field lines. ISCI 1 and 2 observed the opposite same of pularization for about 10 min although the spacecraft were separated by only 9 als in their orbit; this recarriable feature cannot he arplained by either a blattenar; special i or a simple temporal boundar, but could result fro a rapid covenent of the resament region. We argue that the most likely energy source is bounce recorders with medium energy 1% 5 keV) tons. Calculations of the wave Poynting vector at ISEE I support this

J. Ccophys. Ros., Paper 4A0346

*78) have Propagation OBSERVATION OF AN ONCIESATION MAINTEEN FIFTH MELL AT

INREE LOVATIONS

L.J. Cahill (School of Physics and Astronome, Philadrins of Minnesota, Minnesota, Minnesota, School of Physics and Astronome, Philadrins of Minnesota, Minnesota, School Minnesota, Minnesota, School Minnesota, Minnesota, School Minnesota, Minnesota

treased in applitude allow 1910 if and one gone by 1919 up.

The event was observed at the Li-T sarelitic mean the equator in both electric and magnetic field components and at the ground magnetic observatories hiply. Antarctica, and Endervai, Quebec. 15 to he hast of Ot-1 and at opposite ands of an 1 - 4.2 itseld thus. The 180 s and 240 s pulsations were fundamental, coroldal, reconsist oscillations of a magnetic field shell. Since the first 180 s pulsations started and acopped simultaneously at all three locations and the corresponding expects pulsations remained in phase at all three locations, this is interpreted to be a large cale foreidel occillation of noe resonant field shell. Wave propagations.

J. Goophys. Ros., A, Paper 4A0010

WAVE BORNAL DERECTIONS OF CHORUS MEAN THE EQUATORIAL NAVE SURRAL BLACKSTON STATES THE SURRAL BLACKSTON, CALIFORNIA SURRAL RESERVANCE OF PROPERTY OF THE SURRAL STATES OF THE SURRAL SURRAL STATES OF THE SURRAL S

in the near-equatorial region at 1, smalls of o to 7 have been determined from OCO-1 trials is assert coll augmetoster data. Saveral methods were used to estimate the wave normal directions; minimum veriance, imaginary part of cross-spectral matrix, niquavector of Harmitian cross-spectral matrix, and fit of dispersion relations for one-wave and two-wave models to cross-spectral matrix. Comparisons of the methods and results are discussed in detail. Wave propagation at all frequencies within chorus tones was found to occept most frequently along the magnetic field with medical and swarped come angles of \$10, and \$2.20, respectively. All methods of analysis gave similar results. It is concluded that the wave growth is estimate for waves propagating parallol to B. Gur results are consistent with emission to a nerrow beam, but not as a broad anguler distribution. The two wave propagation model typically remulted in negligible improvements in the residual bayon that obstaud by assuming that only one wave was present. In only a propagation modal typically remulted in negligible improvements in the rusidual beyond that obtained by assuming that only one wave was present. In only a few cases dide substantial improvement result. These cases were unusual periods when it was obvious that slautraseous wising. It is monetable that an most cases only one chorus wave was present. In some tases only one chorus wave was present. In some tases the two-wave model gives midscaling indications of waves with large energy fluxes propagating at very oblique engles near the remonster come. This is because the wave group velocity goes to zero mear the resonance come, and if sheetric fluid fare are not used, then a small smouth of magnetic soles in modeled with a large wave energy flux. Some champles have been found of a lewer frequency burst propagating about exactly gloing the magnetic field of lieved by a higher frequency burst propagating about exactly gloing the magnetic field followed by a higher frequency burst propagating the higher frequency burst propagating about exactly gloing the magnetic field followed by a higher frequency burst in large angles to the magnetic field. These paired bursts are questioned to be described by the phonomenon in presented with pulsating entered bursts are part of about frequency that is seconds between parts of berests; the phonomenon in presented. The hardening in the physical implications and ejecused, (the even, wave normals, inspections and ejecused presented the physical implications and ejecused. (The even, wave normals, inspections and ejecused.